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The Internal Wiring of Buildings

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The Internal Wiring of Buildings

Henry Meredith

By H. M. LEAF

A.M.Inst.C.E : M.I.M.E

ILLUSTRATED

WESTMINSTER

ARCHIBALD CONSTABLE AND CO

2, WHITEHALL GARDENS

1899

Butler & Tanner,
The Selwood Printing Works,
Frome, and London.

NOTE

In the preparation of this book I have been greatly assisted by the following firms, who have kindly placed much useful information at my disposal :—

Messrs. W. T. Glover & Co., Ltd.
The General Electric Co., Ltd.
Messrs. Veritys, Ltd.
Messrs. Mavor & Coulson, Ltd.
The Simplex Wiring Co., Ltd.,

and Mr. Musgrave Heaphy, who has kindly allowed me to incorporate the rules of the Phœnix Fire Office.

H. M. LEAF.

November, 1898.

Contents

CHAPTER I

Introduction

ELECTRIC energy is now so universally adopted for lighting, heating, transmission of power and other purposes, that insulated wires or cables (as they are often called) for conveying the current are now fixed in most buildings of any importance. The conditions under which these conductors have to perform their part of carrying the current vary within very wide limits, and it is the object of this treatise to describe the various means of fixing the wires to suit the different conditions under which the current is likely to be employed. The science of fitting up a suitable system of conductors, or "wiring," as it is termed, is not at the present time an exact science, but is rapidly becoming so. Among engineers there are several rival methods of wiring in use, and many discussions have taken place in technical journals, and at the meetings of engineering societies, on the subject of the relative advantages of concentric wiring, wood casing, and systems of iron and other tubing. Each system has merits for special purposes. Generally speaking no one system can be said to be universally better

than another, provided always that due care is taken in fixing the conductors. It has been said with truth that it is better to have an installation consisting of inferior cables and materials, well and carefully fixed, than one in which, although better materials are used, sufficient care has not been exercised in fixing and jointing.

By far the greater number of wiring installations are carried out in buildings in which the current is taken from central stations, so, unless mention is made to the contrary, it is assumed in this book that the current is obtained in this manner, and that it is direct, and not alternating in character.

It is taken for granted the reader has an elementary knowledge of electricity. Without therefore entering closely into the theoretical and fundamental values of electrical units, it may be briefly explained that—

The *volt* is the unit of electric pressure or potential.

The *ampère* is the unit of quantity of current.

The *watt* is the unit rate at which electric energy is produced, and is the product of the pressure and quantity of current.

The *ohm* is the unit of electric resistance, and a pressure of one volt acting on a resistance of one ohm will produce a current of one ampère.

The well-known Ohm's law states that the current in a conductor is directly proportional to the electromotive force (or volts) producing that current, and inversely proportional to the resistance

of the conductor. Thus, calling the electromotive force or volts E, the current C, and the resistance R, Ohm's law states that $\frac{E}{R}=C$; whence $CR=E$, and also $EC=C^2R$.

On these simple formulæ are based nearly all the calculations used in "wiring"; and if once thoroughly grasped, the calculations become quite simple.

A *kilowatt* is one thousand watts, and one kilowatt produced for one hour is known as a Board of Trade unit among central station engineers.

A *megohm* is one million ohms.

The above terms will be frequently employed, and should more exact information be required about them, any elementary text-book on electricity will furnish it; but in order to give the reader some general ideas of their values, it may be of interest to mention that the rate of working known as a horse-power, and estimated by Watt as being equivalent to a weight of 33,000 pounds being raised at the rate of one foot in a minute, is represented electrically by 746 watts, or very nearly three-quarters of a kilowatt. Again, an ordinary 16 candle-power incandescent lamp absorbs electric energy at the rate of 60 watts; hence, as 1,000 watts for an hour constitutes a "unit," it follows that $\frac{1000}{60}=16$ lamps, each of 16 candle-power, burning for an hour, absorb electric energy to the extent of about one unit. Consumers of current from central stations are generally charged by the unit, and the above

example will give a rough idea of the amount of light for one hour that can be obtained per unit. It is here assumed that a 16 candle-power lamp absorbs 60 watts, and such is generally the case. Lamps can, however, be manufactured of the same candle-power to absorb only 40 watts, but they are not so durable as 60-watt lamps.

The usual voltages at which current is supplied from central stations are 100 or 200 volts; assuming a pressure of 100 volts, the resistance of a 60-watt lamp of 16 candle-power can be found by a simple application of Ohm's law thus: $\frac{EC}{E}=C$; but $EC=60$ and $E=100$,

therefore the current $=\frac{60}{100}=\cdot6$ ampère;

and since $\frac{E}{R}=C$, and $C=\cdot6$,

therefore $R=\frac{100}{\cdot6}=133$ ohms.

Numerous simple calculations of this description occur in work connected with wiring, and will be dealt with as occasion arises.

As certain pieces of apparatus are always used in every electrical installation, it may be as well to explain here that a *switch* is an appliance for making or breaking an electric circuit, and consists of a pivoted piece of metal that can be turned in such a manner that it either makes a metallic connection between two conductors or severs it.

Cut-outs, or *fuses*, are appliances for inserting pieces of an easily-fusible metal into the electric

circuit, so that in case of a sudden large increase of current this metal melts and so cuts off the current automatically.

When alternating currents are employed, strictly speaking the calculations derived from Ohm's law should be modified;[1] but in ordinary wiring work, where the capacity of the conductors does not play an important part, and the currents and cables employed are not of an exceptionally heavy nature, the calculations may be carried out on the same lines as those for direct currents.

[1] See Appendix.

CHAPTER II

Electric Cables

OF all the materials used in wiring the most important, from every point of view, are the cables or insulated conductors. These have to be insulated to avoid any possibility of positive or negative wires coming in contact with one another, either directly, owing to the resistance of the lamps being omitted, or indirectly, by moisture or any semi-conducting substance, such as wet plaster or cement. The consequences that may ensue should the positive and negative wires from any cause become directly connected, and thus cut out the resistance of the lamps, may be of a very disastrous nature, and what is known as a "short circuit" at once takes place. This is of the same nature as an explosion, an immense amount of electrical energy being suddenly liberated, which heats the conductors to such an extent that either some portion of the metallic circuit is melted or else damage is done to the machinery producing the current. It is always possible for short circuits to occur; it is necessary, therefore, to distribute what are known

as "fuses" or "cut-outs" at different points in the circuits, so that in the event of a short circuit the fuse, which is made of easily fusible metal, at once melts, owing to the excess of current, and automatically cuts off the current before the copper conductors are sensibly heated.

If moisture finds its way through the insulated coverings to the metallic cores of the conductors, an "earth" connection is thus set up, with the result that the current leaks away from one pole through the moisture or "earth" to the other pole. Electrolytic action then takes place, which dissolves the copper on the positive conductor to such an extent that the circuit is eventually broken. If the moisture is a good conductor a "dead earth" connection is set up, and is likely to be as disastrous as a short circuit. In fact, earth connections generally are a source of such great danger that companies supplying the current from central stations invariably refuse to connect a building to their mains, if any decided earth connection can be detected by means of the testing instruments usually employed.

It will thus be seen that the insulation of cables is of great importance, and when it is remembered that the insulating material must be pliable to allow the cables to be bent, and at the same time of a quality capable of resisting changes of temperature without deterioration, it will be readily understood that india-rubber is one of the best materials that can be employed, as in addition to its other qualities it is a very good non-conductor

of electricity. Many other substances are used, such as bitumen, resin, and paper treated with paraffin; but in the large majority of cases india-rubber is the insulating material employed, and in order to give it more lasting qualities it is generally vulcanized. Without entering into the details of cable manufacturing it must suffice to say that the insulation of a good serviceable conductor for general wiring work will consist of layers of insulated pure and vulcanizing rubber and proofed tape, all thoroughly vulcanized together, then braided and served with a special compound. The diameter of wires forming the conductors of cables is measured by certain gauges which have been in use for periods long before electric lighting came into general vogue. These gauges are known as the Birmingham, Brown and Sharpe, and Standard wire gauges. There are very slight differences between the three, as will be seen by reference to the tables.

For the sake of flexibility and to minimize the chances of breaking a conductor, it is best to use several strands of copper. In practice the smallest size of stranded conductor consists usually of three strands of No. 22 S.W.G.; larger sizes of cables consist of 7, 19, 37, and even 61 and 91 strands for very large sizes. These numbers are chosen because it is found that they give a circular form to the cross section. It is often advisable to use a cable of many strands in preference to one with a smaller number in order to gain the advantage of greater

flexibility. Thus, a 19/18 cable is easier to fix where a large number of corners have to be turned than a 7/14 cable, which is of about the same size but much stiffer to handle.

Sizes of Cables to be Employed.—There are two principal considerations that determine the sizes of conductors to be employed in any building. The first is the amount of heat produced by the current and the resistance of the conductors, and the second is the drop in electrical pressure due to the resistance of the conductor. The conditions in these two respects are to a limited extent analogous to the conditions under which water flows in pipes. Loss of pressure occurs in pipes owing to the friction or resistance to flow, and the cross section has to be proportioned to the quantity of water flowing. Similarly, when an electric current passes along a conductor the latter offers a resistance to its passage in strict proportion to its size or cross sectional area, and if the current is very large and the sectional area small, the loss in electrical pressure may be considerable and cause a very sensible heating of the conductor. If carried to extremes the heating may result in the melting of the conductor. In an incandescent lamp the filament becomes white hot because the resistance is very great and the current large in proportion to the sectional area of the filament.

Table showing the Differences between the various Wire Gauges in use.

Standard Wire Gauge Diameter.			Birmingham Wire Gauge Diameter.			Brown and Sharpe Wire Gauge Diameter.		
No. of Wire.	Inches.	Millimètres.	No. of Wire.	Inches.	Millimètres.	No. of Wire.	Inches.	Millimètres.
0	·324	8·229	0	·340	8·635	0	·3249	8·252
1	·300	7·620	1	·300	7·620	1	·2893	7·348
2	·276	7·010	2	·284	7·213	2	·2576	6·543
3	·252	6·400	3	·259	6·578	3	·2294	5·827
4	·232	5·893	4	·238	6·045	4	·2043	5·189
5	·212	5·385	5	·220	5·588	5	·1819	4·620
6	·192	4·877	6	·203	5·156	6	·1620	4·115
7	·176	4·470	7	·180	4·5719	7	·1443	3·665
8	·160	4·064	8	·165	4·1909	8	·1285	3·264
9	·144	3·658	9	·148	3·7591	9	·1144	2·906
10	·128	3·251	10	·134	3·4035	10	·1019	2·588
11	·116	2·946	11	·120	3·0479	11	·0907	2·304
12	·104	2·642	12	·109	2·7701	12	·0808	2·052
13	·092	2·337	13	·095	2·4129	13	·0720	1·829
14	·080	2·032	14	·083	2·1082	14	·0641	1·628
15	·072	1·829	15	·072	1·8288	15	·0571	1·450
16	·064	1·626	16	·065	1·6510	16	·0508	1·290
17	·056	1·422	17	·058	1·4732	17	·0452	1·150
18	·048	1·219	18	·049	1·2446	18	·0403	1·024
19	·040	1·016	19	·042	1·0668	19	·0354	·900

Standard Wire Gauge Diameter.			Birmingham Wire Gauge Diameter.			Brown and Sharpe Wire Gauge Diameter.		
No. of Wire.	Inches.	Millimètres.	No. of Wire.	Inches.	Millimètres.	No. of Wire.	Inches.	Millimètres.
20	·036	·914	20	·035	·8890	20	·0320	·813
21	·032	·813	21	·032	·8128	21	·0285	·724
22	·028	·711	22	·028	·7112	22	·0253	·643
23	·024	·610	23	·025	·6350	23	·0226	·574
24	·022	·559	24	·022	·5588	24	·0201	·511
25	·020	·508	25	·020	·5080	25	·0179	·455
26	·018	·457	26	·018	·4571	26	·0159	·404
27	·0164	·417	27	·016	·4064	27	·0142	·361
28	·0148	·376	28	·014	·3556	28	·0126	·320
29	·0136	·345	29	·013	·3302	29	·0112	·284
30	·0124	·315	30	·012	·3048	30	·0100	·254
31	·0116	·295	31	·0115	·2920	31	·0089	·2261
32	·0108	·274	32	·0110	·2793	32	·0079	·2007
33	·0100	·254	33	·0100	·2539	33	·0071	·1803
34	·0092	·2337	34	·0095	·2412	34	·0063	·1600
35	·0084	·2134	35	·0087	·2209	35	·0056	·1422
36	·0076	·1930	36	·0079	·2006	36	·0050	·1270
37	·0068	·1727	37	·0073	·1854	37	·0044	·1117
38	·0060	·1524	38	·0068	·1727	38	·0039	·0990
39	·0052	·1321	39	·0063	·1600	39	·0035	·0888
40	·0048	·1219	40	·0058	·1473	40	·0031	·0787

DETAILS OF CONDUCTORS. SHOWING

S.W.G.	At 1,000 per Sq. In., Loss=2½ Volts per 100 Yards.	Diameter of each Wire.		Diameter of the Strand.	
	Ampères.	Inch.	M/M.	Inch.	M/M.
1	70·685	·300	7·620	...	...
2	59·828	·276	7·010	...	...
3	49·875	·252	6·400	...	...
4	42·273	·232	5·893	...	...
5	35·298	·212	5·285	...	...
6	28·95	·192	4·877	...	...
7	24·32	·176	4·470	...	...
8	20·106	·160	4·064	...	...
9	16·28	·144	3·658	...	...
10	12·86	·128	3·251	...	...
11	10·56	·116	2·946	...	...
12	8·49	·104	2·642	...	...
13	6·64	·092	2·337	...	...
14	5·02	·080	2·032	...	...
15	4·07	·072	1·829	...	...
16	3·21	·064	1·626	...	...
17	2·46	·056	1·422	...	...
18	1·80	·048	1·219	...	...
19	1·25	·040	1·016	...	...
20	1·01	·036	0·914	...	...
21	0·804	·032	0·813	...	...
22	0·615	·028	0·711	...	...
3/25	0·9614	·020	0·508	·042	1·018
3/24	1·1631	·022	0·559	·047	1·120
3/23	1·3843	·024	0·610	·051	1·222
3/22	1·8843	·028	0·711	·059	1·425
3/21	2·4608	·032	0·813	·068	1·780
3/20	3·1147	·036	0·914	·077	1·830
3/19	3·845	·040	1·016	·082	2·035
3/18	5·5373	·048	1·219	·102	2·440

DIMENSIONS, CAPACITY, RESISTANCE, AND WEIGHT.

Area.		Resistance at 60° Fahr.			Weight.			S.W.G.
Square Inches.	Square M/M.	Per 1,000 Yards.	Per Mile.	Per Kilo-metre.	Per 1,000 Yards.	Per Mile.	Per Kilo-metre.	
		Ohms.	Ohms.	Ohms.	Lbs.	Lbs.	Kilogrs.	
·070685	45·603	·3461	·609171	·3786	817	1439	405	1
·05982	38·597	·4089	·719719	·4473	691	1218	343	2
·04987	32·176	·4905	·863337	·5366	576	1015	286	3
·04227	27·272	·5787	1·01860	·6330	488	860	242	4
·03529	22·772	·6931	1·21986	·7582	405	718	201	5
·0289	18·678	·8450	1·48723	·9244	334	589	165	6
·0243	15·659	1·0056	1·76993	1·1001	281	495	139	7
·0201	13·035	1·2168	2·14161	1·3311	232	409	115	8
·0163	10·507	1·5022	2·64397	1·6434	188	331	93	9
·0128	8·301	1·9012	3·34626	2·0799	148	261	73	10
·0105	6·818	2·3150	4·07442	2·5326	122	215	60	11
·0085	5·480	2·8800	5·0688	3·1507	98	173	48	12
·0066	4·288	3·6803	6·4744	4·0262	76	135	37	13
·0050	3·243	4·8673	8·5665	5·3248	58	102	28	14
·0040	2·627	6·0089	10·5758	6·5737	47	83	23	15
·0032	2·075	7·6049	13·3847	8·3197	37	65	18·3	16
·0024	1·254	9·9332	17·4826	10·867	28	50	13·5	17
·0018	1·167	13·5198	23·7951	14·790	21	36·8	10·4	18
·0012	0·8107	19·4697	34·2668	21·299	14·5	25·5	7·1	19
·0010	0·6567	24·0354	42·3025	26·294	11·7	20·7	5·8	20
·0008	0·5189	30·422	53·5426	33·281	9·3	16·3	4·6	21
·0006	0·3972	39·729	69·9249	43·463	7·1	12·5	3·5	22
·00096	0·619	25·955	45·671	28·395	11	19	5	3/25
·00116	0·748	21·454	37·761	23·472	13·5	23	6	3/24
·00138	0·890	18·026	31·726	19·720	16	28	8	3/23
·00188	1·212	13·243	23·3080	14·484	22	38	11	3/22
·00246	1·586	10·144	17·853	11·097	28	49	13·9	3/21
·00311	2·000	8·0118	14·100	8·764	36	63	17·8	3/20
·00384	2·476	6·4899	11·420	7·099	44	77	21·8	3/19
·0055	3·547	4·5066	7·931	4·930	64	112	31·7	3/18

DETAILS OF CONDUCTORS (*continued*).

S.W.G.	At 1,000 per Sq. In., Loss=2½ Volts per 100 Yards.	Diameter of each Wire.		Diameter of the Strand.	
	Ampères.	Inch.	M/M.	Inch.	M/M.
7/25	2·200	·020	0·508	·060	1·54
7/24	2·7139	·022	0·559	·066	1·677
7/23	3·2301	·024	0·610	·072	1·83
7/22	4·3968	·028	0·711	·084	2·13
7/21½	5·0469	·030	0·762	·090	2·28
7/21	5·7419	·032	0·813	·096	2·439
7/20½	6·504	·033	0·838	·099	2·51
7/20	7·2678	·036	0·914	·108	2·74
7/19	8·972	·040	1·016	·120	3·04
7/18	12·9207	·048	1·219	·144	3·66
7/17	17·5858	·056	1·422	·168	4·27
7/16	22·989	·064	1·626	·192	4·88
7/15	29·0705	·072	1·829	·216	5·49
7/14	35·889	·080	2·032	·240	6·10
7/13	47·4638	·092	2·337	·276	7·111
7/12	60·6535	·104	2·642	·312	7·926
7/11	75·4576	·116	2·946	·348	8·838
7/10	91·897	·128	3·251	·384	9·753
7/9	116·282	·144	3·658	·432	10·974
7/8	143·55	·160	4·064	·480	12·192
7/6	206·72	·192	4·877	·576	14·931
19/24	7·3807	·022	·559	·110	2·795
19/23	8·7847	·024	·610	·120	3·050
19/22	11·9576	·028	·711	·140	3·555
19/21	15·6159	·032	·813	·160	4·065
19/20	19·765	·036	·914	·180	4·57
19/19	24·400	·040	1·016	·200	5·08
19/18	35·138	·048	1·219	·240	6·10
19/17	47·826	·056	1·422	·280	7·10
19/16	62·467	·064	1·626	·320	8·12
19/15	79·060	·072	1·829	·360	9·14

Area.		Resistance at 60° Fahr.			Weight.			S.W.G.
Square Inches.	Square M/M.	Per 1,000 Yards.	Per Mile.	Per Kilo-metre.	Per 1,000 Yards.	Per Mile.	Per Kilo-metre.	
		Ohms.	Ohms.	Ohms.	Lbs.	Lbs.	Kilogrs.	
·0022	1·419	11·124	19·578	12·44	25·5	45	13·0	7/25
·0027	1·741	9·1952	16·183	10·059	31·5	55	15·6	7/24
·0032	2·064	7·7256	13·597	8·451	37	65	18·3	7/23
·0043	2·773	5·6757	9·989	6·209	51	89	25·2	7/22
·0050	3·225	4·9445	8·702	5·409	58	102	28·7	7/21½
·0057	3·676	4·3460	7·648	4·754	66	116	32·7	7/21
·0064	4·100	4·0864	7·164	4·450	75	132	37·0	7/20½
·0072	4·644	3·4336	6·043	3·755	84	147	41·6	7/20
·0089	5·740	2·7813	4·895	3·042	104	183	51·5	7/19
·0129	8·320	1·9314	3·399	2·112	149	263	74·0	7/18
·0175	11·287	1·4190	2·497	1·552	203	357	100·6	7/17
·0229	14·77	1·0864	1·912	1·188	266	468	131·8	7/16
·0290	18·705	·8584	1·510	·938	336	591	166·6	7/15
·0358	23·091	·6953	1·224	·760	415	730	205·8	7/14
·0474	30·573	·5257	·925	·575	549	967	272·3	7/13
·0606	39·087	·4114	·724	·450	701	1233	347·6	7/12
·0754	48·633	·3307	·5820	·361	872	1533	432	7/11
·0918	59·211	·2716	·4780	·297	1062	1869	527	7/10
·1162	74·94	·2146	·3776	·234	1343	2363	666	7/9
·1435	92·55	·1752	·3083	·191	1660	2921	823	7/8
·2067	133·32	·1207	·2124	·132	2390	4206	1185	7/6
·0073	4·708	3·3877	5·9623	3·706	85	149	42	19/24
·0087	5·611	2·8463	5·0094	3·113	101·5	178	50	19/23
·0119	7·67	2·0910	3·6801	2·287	138	242	68	19/22
·0156	10·06	1·6011	2·8179	1·752	180	316	89	19/21
·0197	12·70	1·2650	2·2264	1·384	228	401	113	19/20
·0244	15·73	1·0247	1·8034	1·121	282	496	139·8	19/19
·0351	22·63	·7115	1·2522	·778	406	714	201	19/18
·0478	30·83	·5228	·9201	·572	553	973	274	19/17
·0624	40·24	·4002	·7043	·438	722	1270	358	19/16
·0790	50·95	·3162	·5565	·346	914	1608	453	19/15

DETAILS OF CONDUCTORS (*continued*).

S.W.G.	At 1,000 per Sq. In., Loss=2½ Volts per 100 Yards.	Diameter of each Wire.		Diameter of the Strand.	
	Ampères.	Inch.	M/M.	Inch.	M/M.
19/14	97·604	·080	2·032	·400	10·1
19/13	129·083	·092	2·337	·460	11·6
19/12	164·953	·104	2·642	·520	13·2
19/11	205·215	·116	2·946	·580	14·73
19/10	249·870	·128	3·251	·640	16·25
19/9	316·241	·144	3·658	·720	18·2
19/8	390·422	·160	4·064	·800	20·3
19/7	472·410	·176	4·470	·880	22·3
37/24	14·344	·022	·559	·154	3·9
37/23	17·157	·024	·610	·168	4·2
37/22	23·354	·028	·711	·196	4·97
37/21	30·499	·032	·813	·224	5·69
37/20	38·603	·036	·914	·252	6·4
37/19	47·656	·040	1·016	·280	7·1
37/18	68·629	·048	1·219	·336	8·5
37/17	93·409	·056	1·422	·392	9·9
37/16	122·004	·064	1·626	·448	11·3
37/15	154·411	·072	1·829	·504	12·8
37/14	190·630	·080	2·032	·560	14·2
37/13	252·110	·092	2·337	·644	16·3
37/12	322·169	·104	2·642	·728	18·4
37/11	400·802	·116	2·946	·812	20·6
37/10	488·018	·128	3·251	·896	22·77
37/9	617·646	·144	3·658	1·008	25·6
37/8	762·520	·160	4·064	1·120	28·4
61/24	23·788	·022	·559	·198	5·031
61/23	28·3139	·024	·610	·216	5·490
61/22	38·540	·028	·711	·252	6·399
61/21	50·3316	·032	·813	·288	7·317
61/20	63·706	·036	·914	·324	8·226

Area.		Resistance at 60° Fahr.			Weight.			S.W.G.
Square Inches.	Square M/M.	Per 1,000 Yards.	Per Mile.	Per Kilo-metre.	Per 1,000 Yards.	Per Mile.	Per Kilo-metre.	
		Ohms.	Ohms.	Ohms.	Lbs.	Lbs.	Kilogrs.	
·0976	62·95	·2561	·4507	·280	1128	1985	559	19/14
·1290	83·20	·1937	·3409	·212	1491	2624	739·5	19/13
·1649	106·36	·1515	·2666	·166	1906	3354	945	19/12
·2052	132·35	·1218	·2142	·133	2372	4174	1176	19/11
·2498	161·12	·1000	·1760	·109	2888	5082	1432	19/10
·3162	203·94	·07906	·1391	·0865	3655	6432	1812	19/9
·3904	251·80	·06406	·1127	·0700	4513	7942	2238	19/8
·4724	304·69	·05292	·09313	·0579	5461	9611	2708	19/7
·0143	9·22	1·7396	3·0616	1·903	165	290	81·8	37/24
·0171	11·02	1·4647	2·5724	1·599	198	348	98	37/23
·0233	15·02	1·0737	1·8897	1·175	270	475	134	37/22
·0304	19·60	·8222	1·4470	·8994	352	619	174·5	37/21
·0386	24·89	·6496	1·1432	·7106	446	784	221	37/20
·0476	30·70	·5262	·9261	·5756	550	968	272·8	37/19
·0686	44·24	·3654	·6431	·3997	793	1395	393	37/18
·0934	60·24	·2684	·4723	·2936	1080	1900	535	37/17
·1220	78·69	·2055	·3616	·2248	1410	2481	699	37/16
·1544	99·58	·1624	·2858	·1776	1785	3141	885	37/15
·1906	122·93	·1315	·2314	·1438	2203	3877	1093	37/14
·2521	162·60	·09947	·17506	·1088	2914	5128	1445	37/13
·3221	207·75	·07783	·13698	·0851	3723	6552	1847	37/12
·4008	258·51	·06265	·11026	·0685	4633	8154	2298	37/11
·4880	314·76	·05138	·09042	·0562	5641	9928	2798	37/10
·6176	398·3	·04060	·07145	·0444	7140	12566	3541	37/9
·7625	491·8	·03288	·05786	·0360	8815	15514	4372	37/8
·02378	15·3	1·0551	1·8569	1·154	275	484	136	61/24
·02831	18·2	·8865	1·5602	·970	327	575	162	61/23
·03854	24·8	·6513	1·1462	·7125	446	784	221	61/22
·0503	32·4	·4987	·8777	·5455	572	1006	284	61/21
·0637	41·0	·3940	·6934	·4310	736	1295	365	61/20

DETAILS OF CONDUCTORS (*continued*).

S.W.G.	At 1,000 per Sq. In., Loss=2½ Volts per 100 Yards.	Diameter of each Wire.		Diameter of the Strand.	
	Ampères.	Inch.	M/M.	Inch.	M/M.
61/19	78·645	·040	1·016	·360	9·144
61/18	113·255	·048	1·219	·432	10·971
61/17	154·149	·056	1·422	·504	12·798
61/16	201·339	·064	1·626	·576	14·634
61/15	254·818	·072	1·829	·648	15·461
61/14	314·588	·080	2·032	·720	18·288
61/13	416·046	·092	2·337	·828	21·033
61/12	531·661	·104	2·642	·936	23·778
61/11	661·427	·116	2·946	1·044	26·514
61/10	805·356	·128	3·251	1·152	29·259
91/18	169·202	·048	1·219	·528	13·409
91/17	230·296	·056	1·422	·616	15·642
91/16	300·797	·064	1·626	·704	17·886
91/15	380·695	·072	1·829	·792	20·119
91/14	469·990	·080	2·032	·880	22·352
91/13	621·567	·092	2·337	1·012	25·707
91/12	794·294	·104	2·642	1·144	29·062
91/11	988·162	·116	2·946	1·276	32·406

In order to calculate the energy lost in heating, due to the passage of the current along conductors, it becomes necessary to know the resistance in ohms of given lengths of the cables employed. Now the "specific resistance" of copper, *i.e.* the resistance of a piece of given dimensions compared with the resistance of a piece of silver of similar

Area.		Resistance at 60° Fahr.			Weight.			S.W.G.
Square Inches.	Square M/M.	Per 1,000 Yards.	Per Mile.	Per Kilo-metre.	Per 1,000 Yards.	Per Mile.	Per Kilo-metre.	
		Ohms.	Ohms.	Ohms.	Lbs.	Lbs.	Kilogrs.	
·0786	50·6	·3191	·5616	·3490	909	1599	451	61/19
·1132	73·0	·2216	·3900	·2424	1309	2303	649	61/18
·1541	99·3	·1623	·2865	·1781	1781	3134	883	61/17
·2013	129·8	·1246	·2192	·1363	2327	4095	1154	61/16
·2548	164·3	·09850	·17336	·1077	2945	5183	1460	61/15
·3145	202·8	·07979	·14043	·0872	3636	6399	1803	61/14
·4160	268·3	·06033	·10618	·0660	4809	8463	2385	61/13
·5316	342·8	·04721	·08308	·0516	6145	10815	3047	61/12
·6614	426·6	·03795	·06679	·0415	7646	13456	3792	61/11
·8053	519·4	·03116	·05484	·0340	9309	16383	4617	61/10
·1692	109·1	·14857	·02615	·1625	1956	3442	970	91/18
·2302	148·4	·10915	·1921	·1194	2661	4683	1319	91/17
·3007	193·9	·08357	·1471	·0914	3476	6117	1724	91/16
·3806	245·4	·06603	·1162	·0722	4400	7744	2182	91/15
·4699	303·0	·05348	·0941	·0585	5432	9560	2694	91/14
·6215	400·8	·04044	·0711	·0442	7185	12645	3563	91/13
·7942	512·2	·03164	·0556	·0346	9181	16158	4553	91/12
·9881	637·3	·02543	·0447	·0278	11422	20102	5665	91/11

dimensions, has been ascertained with great accuracy, and taking the resistance of silver as unity, the relative resistance of annealed copper is 1·063 at 0° Centigrade. If, therefore, the actual resistance in ohms of a given length of silver wire, say one yard long and $\frac{1}{100}''$ diameter, is known, the resistance

of a similar piece of copper wire can be calculated, and from this again any lengths of copper conductors, always bearing in mind that the resistance is proportional to the length and inversely proportional to the cross sectional area. Complete tables are here given of the more usual sizes of conductors used in wiring, giving the resistances, sizes, weights and diameters, including insulation, and the current giving $2\frac{1}{2}$ volts drop in pressure for every 100 yards of double run.

Suppose, for instance, it is required to know the resistance of 100 yards of 3/22 cable, a size very frequently used in wiring work. From books we find that the resistance of the above-mentioned yard of silver wire of $\frac{1}{100}''$ diameter is ·2714 ohm. Therefore the resistance of a similar piece of annealed copper wire is $\cdot 2714 \times 1\cdot 063 = \cdot 2885$ ohm. The sectional area of wire $\frac{1}{100}''$ diameter is ·0000785□″, and of a single wire of 22 gauge (of which the diameter is ·028″) is ·0006154□″. A 3/22 stranded wire has therefore a sectional area of $\cdot 000615'' \times 3 = \cdot 001846$□″. The resistance then of 1 yard is $\cdot 2885 \times \frac{\cdot 0000785}{\cdot 001846} = \cdot 01226$ ohm. Therefore the resistance of 100 yards of 3/22 is 1·226 ohms. This number is not quite the same as that given in the table, the explanation being that the sectional area is slightly larger than ·001846 owing to the fact that the three strands of wire are put together in a slightly spiral form,

consequently the sectional area is greater than if all the wires were perfectly straight. In the tables, account is taken of the decrease of resistance due to the spiral winding of the stranded conductors.

Current Density in Conductors.—The greater the current that passes through a conductor of given diameter the greater is the loss in pressure and the heat produced; hence it is necessary to fix some proportion between the diameters of conductors and the current they shall carry, in order to avoid overheating. For the internal wiring of buildings any danger of overheating can be avoided by using conductors of such a sectional area that the current in them shall not be proportionately greater than 1,000 ampères per square inch of sectional area of conductor, or, in other words, the "current density" must not exceed 1,000 ampères per square inch. Thus the maximum current that should be carried by a 3/22 cable of which the sectional area is ·0018″ is 1,000 × ·0018 or 1·8 ampères. It will be seen from this that it is only necessary to multiply the area of a conductor (in square inches) by 1,000 to find the maximum carrying capacity in ampères. In order to avoid undue loss of pressure, it is very frequently advisable to employ larger conductors than those given by this rule, but as regards heating effects only, the 1,000 ampères per square inch rule is very largely adopted as a practical rule of thumb guide for determining the sizes of conductors. This rule is empirical and can be relied on

to this extent only, that it will not under any circumstances permit pure copper conductors to become dangerously hot, but it is no guide at all as to the ultimate temperature the conductor will reach; this depends on a variety of circumstances into which it is not necessary to enter here.[1] In the tables of details of conductors, the resistances, weights, areas, loss in pressure per 100 yards run are given, so that any calculation requiring these figures can be easily made.

Where the conductors are not of pure copper, as in switchboards, wall sockets, ceiling roses, etc., it is necessary to allow a much lower current density, as the brass or gun-metal of which these are made has a higher specific resistance than pure copper; consequently the heating effect with a given current is greater, and the current density should not be allowed under any circumstances to exceed 500 ampères per square inch.

If the current density is kept within the 1,000 ampères per square inch limit, it will be found that in most buildings not only is there no danger from overheating, but also that the drop in pressure at the ends of the circuits is not excessive, being generally not more than 2 or 3 per cent. of the total voltage. In specifications issued by consulting engineers, it is often stipulated that this drop shall not exceed 2 per cent. at the ends of the longest circuits. In buildings, therefore, where the runs are likely to be long, it becomes necessary to

[1] See Appendix.

calculate carefully the sizes of the conductors, to see if the 1,000 ampère per square inch rule allows sufficient area of conductor.

Now the electrical pressure or "voltage" employed determines. largely the size of conductors to be employed; thus it has been mentioned above that an incandescent lamp of 16 candle-power requires 60 watts to bring it to a normal incandescence. This energy may be delivered theoretically at any voltage, provided the lamp is suitably made. If, for instance, a pressure of 10 volts were employed, the current would be $\frac{60}{10} = 6$ ampères; but if it should be 200 volts, the current becomes $\frac{60}{200} = \cdot 3$ ampère, or $\frac{1}{20}$ of the former amount. It is obvious, therefore, that a conductor to carry 6 ampères must be 20 times larger than one used to carry ·3 ampère, provided the current density in each is the same. Similar conditions would obtain in two water pipes delivering the same energy in water, but at pressures differing as 1 : 20. The pipe carrying the water at the lower pressure would require a sectional area 20 times larger than that of the other. By increasing the voltage of lamps, therefore, the current can be correspondingly decreased and a large saving effected in the copper employed in the conductors. This is of great practical importance, and there is a general tendency to increase the voltage of lamps. At the present time the limit is

about 250 volts, and it is not improbable that even this high voltage may be increased. It must be remembered, however, that with the higher pressures employed the difficulties of efficiently insulating the conductors increase, and special apparatus has to be introduced in order to ensure safety to the consumers of electrical energy. It may be mentioned here that wires for electric bell connections are very lightly insulated simply because the pressure is very small (not exceeding one or two volts), consequently there is little danger of the insulation breaking down.

By raising the voltage then the current is decreased, and this decrease means also a smaller loss of pressure over a given resistance. There is therefore a double gain, decrease of loss of pressure and diminution of current. This follows directly from Ohm's law, which states that $E = CR$ or $EC = C^2R$.

From this it will be seen that any diminution of current in a given conductor causes the power (EC) lost to vary inversely as the square of the current. The power thus lost is frequently referred to as the C^2R or frictional losses.

In order to gain the full advantage of higher pressure, supply companies for direct current are making great efforts to induce their customers to adopt higher voltage lamps; and in cases where this has been done, it has been possible to extend the lighting areas from given centres to a very large extent.

An example may make this more clear. Suppose

100 16-c.p. lamps of 60 watts each and 100 volts are fixed at the end of a 19/16 cable 100 yards long altogether. The resistance of this length is ·0406 ohm, and the current taken by the lamps is $100 \times \cdot6 = 60$ ampères. The loss in pressure along this cable will be $60 \times \cdot0406 = 2\cdot439$ volts, and the loss in watts $60 \times 2\cdot439 = 146\cdot37$ watts. If now the voltage of the lamps is increased to 200 volts the current is halved to 30 ampères. The resistance of the cable remains the same, and the loss in pressure becomes $30 \times \cdot0406 = 1\cdot219$, and the loss in watts $30 \times 1\cdot219 = 36\cdot59$. This is $\frac{1}{4}$ the watts lost in the former case. In order to obtain the same loss in watts in the same length, the cable at the higher voltage would be $\frac{1}{4}$ the size, or, to put it in another way, the same loss in watts would occur if the cable were four times as long. In the wiring of buildings a considerable economy can be effected in the size of conductors by increasing the pressure, and in cases where the wiring has already been put in to carry current for lamps of 100 volts, if the voltage is changed to 200, no less than 4 times the number of lamps can theoretically be used with the same loss in watts. In practice, however, it is not advisable to allow more than double the number of lamps, for the current density is only halved, and if the conductors were originally put in allowing 1,000 ampères per square inch, it is not usual to allow a greater current density than this.

CHAPTER III

General Arrangement of Conductors and Cut-outs in Buildings

AS a general rule the supply of current from a central station or other source is taken into a building in the lower floor, a convenient position being selected for the termination of the mains. At this point a fusible cut-out is placed on each conductor or "pole," and the conductors are then run to the various points throughout the building, and can be gradually diminished in size as they get nearer the top of the building, as the number of lights they have to supply is diminished. It is of the first importance to remember that wherever the size of conductor is diminished a double-pole cut-out *must* be placed where this change of area takes place; or, in other words, the cut-outs *must be placed at the roots of the branches* from the mains. The function of these cut-outs is not to prevent the lamp filaments from giving way, owing to excess of pressure, but to protect the conductors from dangerous overheating, due either to short circuits or excessive leakage of current.

In towns and situations where the current is obtained from a central station, the work of bringing the mains into the building from the street is undertaken usually by the company supplying the current, and in most cases these short lengths are run in iron barrel, which is by far the most efficient protection for work of this description.

After leaving the company's double-pole fuse, the conductors are run first to a meter, and then to a main double-pole switch and fuse, which must be placed as close as possible to the company's fuses, care being taken that no current whatever is taken from the mains between this switch and company's fuse, otherwise the main switch will not control every light in the building; and, in addition, should any fault be developed behind the main switch, there is no means of cutting off the current, as the fuses of the supply company are generally very large, and not likely to melt except in extreme cases.

After leaving the main double-pole switch and cut-out, the conductors should be taken to various distributing fuse-boards, placed in convenient positions throughout the building, and smaller conductors are run from these boards again to the various points where the lights are required. Distributing boards consist of groups of fuses on each pole fixed to an insulated base, and enclosed usually in boxes to protect them. Later on a fuller description of various fuses will be given.

There are two simple methods of arranging the mains in a building: either one pair of mains can

be run, and the various sub-distributing fuse-boards fed from these by short branches of the same size as the mains, or else the mains themselves can be subdivided at a point where a fuse-box is placed, and from this again smaller mains are run to the smaller distributing boxes. The first plan is suitable for small buildings, as it is very simple, and the second plan for larger buildings, as it admits of each section of the mains being tested separately when necessary. This is of great importance, as it is often difficult to localize faults unless the circuits can be divided into sections. These two systems are diagrammatically shown in Figs. 1 and 2.

Three-wire System.—In large buildings, in which the number of lights is likely to exceed 100, it is a very usual practice to introduce what is known as the "three-wire system." The object of this system is to gain the advantages of higher voltage without increasing the actual voltage of the lamps. The method employed is simple, being merely the connection of two circuits, each supplying current at a given voltage into one system, whereby the pressure is doubled. Thus, *A* and *B* are two separate systems, each supplying current at 100 volts to a number of lamps. If now the two systems are joined together, as in *C*, the pressure over the whole installation becomes 200 volts, but the lamp pressure remains as before, or 100 volts, because the middle wire is so connected that there is never more than 100 volts between it and each of the outside

conductors. The advantage of this system may

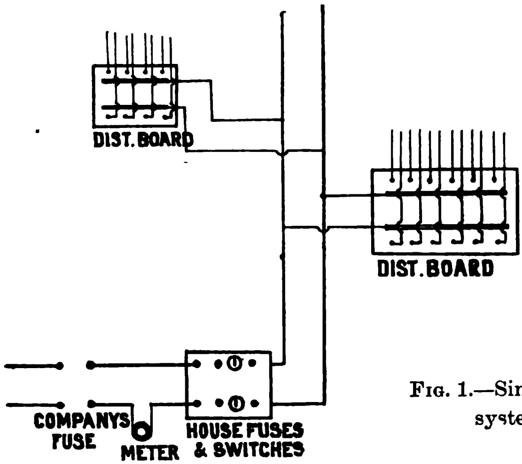


Fig. 1.—Single main system.

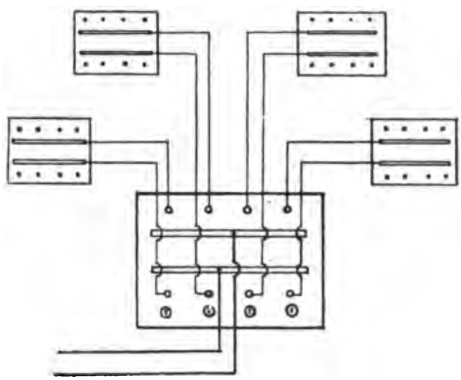
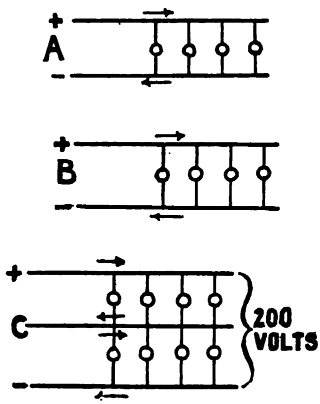


Fig. 2.—Sub-divided main system.

not at first be apparent, as the current in the two

outer conductors is the same if the two systems are connected together or separate, but in C it will be noted that the current in the middle wire is marked by the arrows as flowing in opposite directions. This means that the two currents neutralize one another in this portion, and that there is no resultant current in this wire unless the number of lamps on each side of the middle wire is unequal, in



Three-wire system.

which case the balance flows back by it. The gain, therefore, consists in this: that if the current in the two sides of the middle wire is balanced, the current flows through a much shorter length of conductor than it would do otherwise, consequently the loss in pressure is much less. In fact, assuming the current to be taken from the ends of long lengths of conductors, if a three-wire system with

the two portions equally loaded is employed instead of two separate systems, the current will travel through half the length of conductors, *i.e.* two wires instead of four, and the loss of pressure will be halved.

In practice it is seldom if ever possible to so arrange matters that the current is the same on each side of the middle wire, consequently there is generally a current flowing in the middle or balancing wire. As lamps are switched on or off on each side of the middle wire the balance is altered, and if, as is sometimes the case, all the lamps on one side are switched off, the system becomes an ordinary one of two conductors only. This is an extreme case, and care should be taken to arrange the lighting so that the number of lamps alight on each side of the middle wire is about the same. If this is done the middle wire can be made appreciably smaller in area than the outside wires. The exact size to be used can only be approximately determined, and it is usual to allow it to be from about one-third to two-thirds the area of the outer conductor, according to the possibility of obtaining good balancing on each side. Figs. 1 and 2 show two methods of connecting the mains throughout a building to the different fuse-boards on the three-wire system. Fig. 1 shows the simpler method, which may be used for smaller buildings; Fig. 2 the method for larger buildings, where it is necessary to be able to subdivide sections of the mains for testing purposes. In this latter case the full

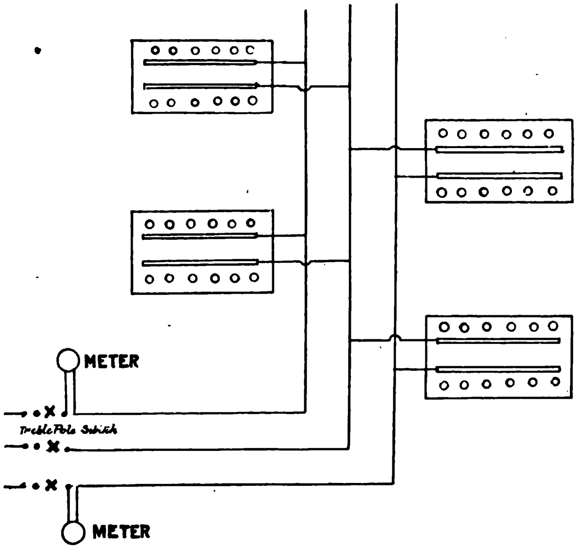


FIG. 1.—Three-wire system. Simple main.

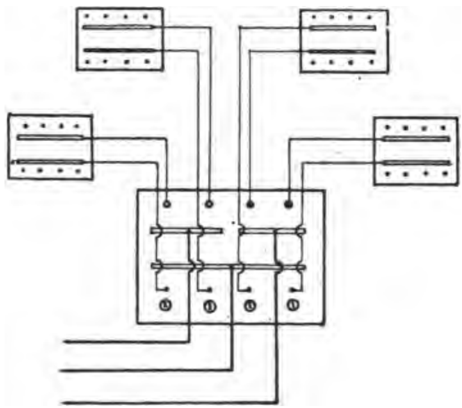


FIG. 2.—Three-wire system. Subdivided mains.

advantage of the three-wire system is only gained up to the main distributing board.

The three-wire system is of great advantage to companies supplying current, inasmuch as it enables them to gain the advantage of the higher voltage. It is not, however, of such corresponding advantage to the consumers, as the various circuits have to be run back to a central distributing board before any advantage can be taken of the system. This is seen in Fig. 2. In buildings where the current amounts to 50 ampères, most supply companies insist that the three-wire system shall be employed.

In order to calculate the loss in pressure in the conductors fixed in a building, we will take as an example an ordinary dwelling-house, in which say 100 lamps of 16 candle-power are fixed and all alight at the same time. We will assume that 100 volts is the pressure, and that each lamp takes 60 watts. Under these circumstances, the current in the mains supplying the whole house will be 60 ampères, distributed as follows:—

3rd floor . .	10 lamps, or	6 ampères.
2nd " . .	15 " "	9 "
1st " . .	30 " "	18 "
Ground floor .	30 " "	18 "
Basement .	15 " "	9 "
	100 lamps.	60 ampères.

We will assume the current for the lamps on the various floors is taken from 3 distribution boards shown on the 1st and 2nd floors and the basement.

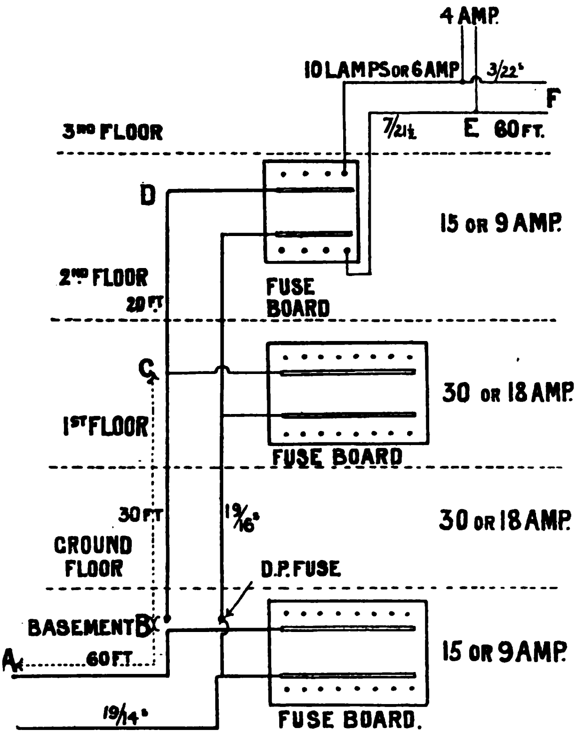


Diagram for calculating loss in mains.

Now it may be convenient to take current from any given fuse-board to supply lamps on the floors immediately above or below, therefore the number of

ampères given on each floor is no accurate indication from which fuse-board the current is taken. Thus the 30 lamps on the ground floor may be supplied partly from the 1st floor and partly from the basement. We will assume, therefore, that 15 ampères is taken from the 2nd floor board, 30 ampères from the 1st floor board, and 15 ampères from the basement board. At each of the points B, C, and D, 15, 30, and 15 ampères respectively are taken from the mains; therefore the portion $C\,D$ carries 15 ampères, $B\,C$ 45 ampères, while $A\,B$ carries the full 60 ampères. The distances of these various portions are given as 20, 30, and 60 feet respectively; it becomes therefore quite easy to calculate their resistances and the drop of pressure due to the flow of current in them. As that portion of the mains above B, however, does not carry the full current, it is assumed that the mains are reduced at this point and a pair of cut-outs fixed.

It will be seen from the tables of cables above given that to carry a current of 60 ampères a 19/14 must be used, assuming a current of 1,000 ampères per square inch is used. Now the resistance of this cable per 100 yards is ·0256 ohm; therefore, if 60 feet run is required, as shown in the figure the resistance will be $\cdot 0256 \times \frac{60 \times 2}{100 \times 3} = \cdot 0102$ ohm, and the loss in pressure $\cdot 0102 \times 60 = \cdot 61$ volt.

Here the length 60 is multiplied by 2 to allow for both positive and negative wires, or "lead" and "return" as they are generally called. From B to

C a smaller conductor can be used to carry 45 ampères, and we will assume this part of the main is taken right up to the fuse-board at *D*. To carry 45 ampères at 1,000 current density a 19/16 may be used, and the resistance between *B* and *C*, calculated as before, becomes ·008, the resistance per 100 yards of 19/16 being ·04 ohm, and the length 30 feet doubled as before; the loss in pressure is therefore $\cdot008 \times 45 = \cdot36$ volt. In the last portion between *C* and *D* the resistance becomes ·0046, and the loss in pressure $\cdot0046 \times 9 = \cdot041$ volt.

Taking the pressure at *A* as 100 volts, the pressures at *B*, *C* and *D* by subtraction are found to be respectively, 99·36, 99·03 and 98·9 volts.

We now come to the sub-mains of 5 ampères each, and we will take one as an example, assuming that from the board at *D* the largest branch of say 60 feet run of 7/21½ takes 6 ampères to *E*, and that for another 20 feet beyond this a branch of 3/22 takes 1 ampère to the point *F*.

The resistance of 60 feet run of 7/21½ is seen to be ·2 ohm, and the loss of pressure $\cdot2 \times 6 = 1\cdot2$ volts. Similarly the resistance of the 3/22 is ·17 ohm, and the loss in pressure $\cdot17 \times 1 = \cdot17$ volt.

Adding these two losses in pressure together, we get the loss from *D* 1·37 volts, and the total loss from *A* $1\cdot1 + 1\cdot37 = 2\cdot47$ volts.

Assuming therefore that the particular sub-branch we have taken is as large as any in the building, the maximum drop in pressure over the whole building has been obtained.

In this particular case it will be seen that the conductors are within the 1,000 ampère per square inch limit. In large buildings, where the runs are long, in order to avoid a loss of pressure greater than 2 per cent. it may be necessary to put in conductors allowing 800 ampères per square inch.

In a manner similar to the above the drop in

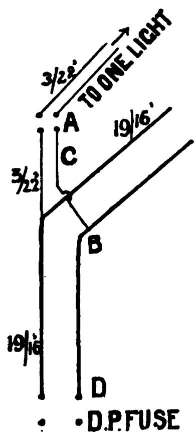


Diagram showing position of fuses.

pressure may be calculated in any building, and in the case of a three-wire system it is best to assume all the lamps on one side of the middle wire are switched off, and then calculate the drop as in an ordinary two-wire system as above.

Fusible Cut-outs.—In the arrangement of wiring in a building the correct placing of the fuses is of primary importance. The diagrams already given

will indicate to some extent how those fuses should be placed, and it has been stated that wherever the conductors are reduced in area a cut-out should be fixed. This is a regulation always insisted on by fire insurance companies, and should receive careful attention, otherwise sections of the conductors may become dangerously heated and cause considerable damage.

Suppose, for instance, a small conductor, say a 3/22, supplying current for one light, is connected to a much larger main, say 19/16 cable, carrying current for a considerable number of lamps, and the small fuses are placed at *A* instead of *B*. If now a short circuit should occur anywhere between *A* and *B*, say at *C*, there is a sudden rush of current through the small conductors, which heats them to such an extent that they attain a dangerous heat, or else the larger fuses at *E* are melted. In any case some part of the circuit must give way, probably setting fire to the insulation, and the rupture takes place at the weakest point. It is obvious that if the small fuses had been placed at *B* the fusible wire would have melted at once and no undue heating of the conductors have taken place, for fuses are supposed to melt at currents about 50 per cent. in excess of the lamp currents controlled by the fuses.

Fuses and fuse-boards should always be placed in easily accessible positions, and should be so designed that the fuses are quite easy to repair. When electric lighting was first introduced, small branches were taken off the mains at any convenient points,

and crude round porcelain fuses fixed indiscriminately under floors or in ceilings as might be most convenient to the wiring contractor. These were always getting out of order, and when broken were liable to set up earth connections, so that it was no uncommon thing to find that even when lamps were switched off the lights did not go out, owing to the earth connections completing the circuits. Now, however, it is the general practice to group fuses together, and to place them in boxes in convenient positions, so that if a fuse melts it can be easily replaced, and should any fault occur in the wiring, all the small branches can be tested from these centres of distribution. These fuses are on each pole, so that they may act in every case of excess of current due either to short circuiting or leakage to earth on either pole. For incandescent lighting it is a usual practice to run circuits of about 5 ampères or 8 lamps of 16 c.p. at 100 volts from the double pole fuses in the sub-distribution boards, using conductors of 7/21½ gauge, and to put no further double pole fuses, even if the branches are further reduced to 3/22 in size. The fact that these small sub-branches are thus reduced in area without the protection of fuses is no doubt not recognised by the authorities, and many engineers will not allow it. On the other hand the fuses for a 5 ampère circuit are so very fine that no damage can possibly be done to the finest flexible cord by overheating due to short circuit, provided it is protected by a suitable 5 ampère fuse. In most

cases flexible cords are protected by fuses in ceiling roses and wall sockets, but the fuses in this case are on one pole only. The size of conductor employed for a 5 ampère circuit used to be a single 14 Standard wire gauge, but as it is not advisable to use single conductors, as before explained, a wire of 7/21½ is now nearly always employed, which is very nearly the same size. As the number of lights is reduced a 3/22 is used for 1 to 3 lights, and (excepting flexible cords) this is generally the smallest size of conductor employed for electric lighting purposes.

In order to avoid having any joints made in conductors, some engineers so arrange the wiring that the conductors from each point of light are run right back to the sub-distributing boards. This system is extremely expensive, but is largely used in shipwork, where salt water is certain to find out any weak places in badly made joints. It is not usual to employ it in buildings on account of the cost and the multiplication of conductors it entails.

Alternating Currents.—The general arrangement of conductors and fuses applies to wiring for alternating currents much in the same way as for direct currents. It must be borne in mind, however, that if iron barrel is used to protect the wires it is usual to place *both* conductors in the same tube to avoid induction effects due to alternating currents, which, with heavy currents, would cause undue loss in pressure if each conductor were placed in a separate iron tube.

Arc Lamps and Motors.—Where arc lamps, either

singly or in pairs, are employed, each circuit must have its own double pole, switch and fuse on the distribution board. With direct currents, arc lamps require from 40 to 45 volts each to ensure steady running; it is therefore usual to put them up in pairs on 100 volt circuits, with a resistance in each circuit to absorb about 10 volts. A resistance is essential to the working of a direct current arc lamp as it acts as a regulator, and the more there is of it in circuit the better the lamps will work.

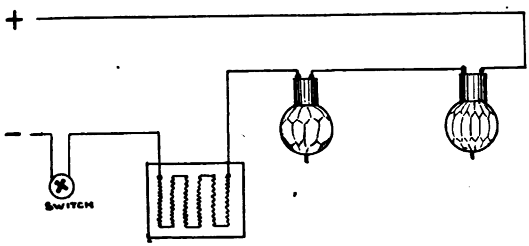


Diagram showing connections for two arc lamps in series.

It is therefore a very usual practice in mills and factories, *i.e.* where a large number of arc and incandescent lamps are used together at the same time, to fix the voltage at 110, of which the arc lamps absorb about 90 and the resistance 20. The power lost in the resistance is considerable, but the increased steadiness in the light more than compensates for this.

Arc lamps worked by means of alternating currents have this advantage over direct current

lamps, that "choking coils" take the place of the resistances, and very little power is lost in these coils; but the amount of light given out by an alternating arc lamp is less than that given out by a direct current lamp taking the same current.

The diagram shows how the connections for direct current arc lamps are made for working 2 in series on 100 or 110 volt circuit. The connections for alternating currents are the same, the choking coil taking the place of the resistance.

Resistances and choking coils are always mounted on insulators, and it is best to enclose them in well-ventilated iron cases, as they get hot when the current passes through them. Similarly the arc lamps themselves must be hung on insulators, and the working parts of the lamps insulated from the outer framework, in order to avoid any possibility of earth connections being set up through accidental contact of the outer casing with metal connected to earth.

The same remarks apply equally to motors. If resistances are employed with them they must be protected and insulated, and the motors themselves should be fixed to strong wooden frameworks by means of coach screws in such a manner that there can be no direct electrical earth connection between the bedplate of the motor and the earth.

CHAPTER IV

Jointing and Wood-casing System of Wiring

JOINTING.—One of the most important, if not the most important, part of the wiring of buildings is the making of proper joints in the conductors. Badly made joints are very likely to give trouble in course of time, although it may be years before the defects become apparent. Unfortunately, there are no means of detecting bad joints when once they have been concealed in the casings or tubes, and nothing is more annoying than to discover their existence after the completion of a building in which, perhaps, there are elaborate decorations and paintings. Many thousands of pounds have been spent in rectifying joints which have been discovered to be bad too late, and it cannot be urged too strongly that the utmost care should be exercised in the first instance in putting in work that is thoroughly reliable. To make good joints takes time and experienced workmen—any man can make bad joints and scamp the work, and it is hardly an

exaggeration to say that in nine cases out of ten in cheap and bad work the faults can be traced to bad jointing. Most engineers can show specimens of inferior joints taken from buildings where faults have appeared, and it is very interesting to note how moisture has in some cases made its way to the conductors, and in others how defective soldering has led to a break in the circuit or corrosion of the conductors due to the use of spirit as a flux, instead of resin. After joints are made and insulated, it is sometimes found that the insulation of the whole is not as good as it should be. This is probably due to allowing the outer braiding of the cables to come in contact with the conductors, in which case the insulation is at once lowered, as the braiding is a partial conductor and should be very carefully stripped back, thus exposing the vulcanized rubber, over which the pure rubber strip is subsequently wound.

In the case of small conductors, not larger than say 7/14, it is comparatively easy to make joints, but for cables larger than this it is not so easy. In fact, the work is somewhat of the same nature as splicing ropes, and just as difficult to perform neatly and efficiently. In the case of cables of large diameter jointing becomes a work of considerable difficulty, great skill being required to produce a really satisfactory result. No better description of the best method of making joints and insulating them can be given than the published instructions of some of the leading cable manufacturers, and the follow-

ing illustrations and instructions are issued by Messrs. Verity, Ltd., of Birmingham:—

"First cut the taped or braided outer covering of the cable off for a distance of about 6 inches from the end of each cable. Next cut the vulcanized or pure rubber and other coverings at a distance of about 4½ inches from the cable ends, and remove it entirely, leaving the conductor exposed. The 1½

JOINTING.

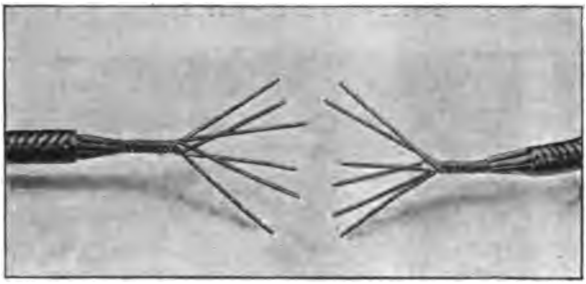


FIG. 1.

inches of rubber left standing should be neatly tapered with a sharp knife, as shown in the illustrations. The strands are then separated ready for 'marrying,' as shown in Fig. 1, and the centre wire or core cut out. Before jointing all the wires must be most carefully cleaned with fine emery paper, and the body of the conductor tightly twisted together up to the point where the strands separate.

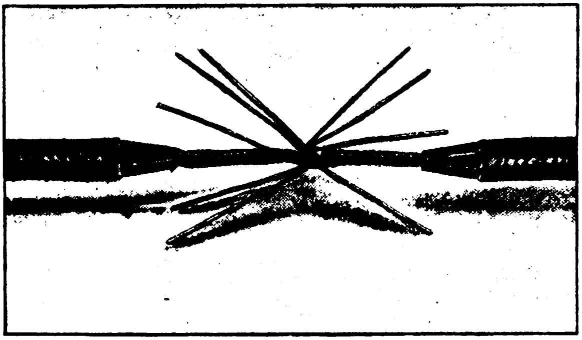


FIG. 2.—The Ends "married."

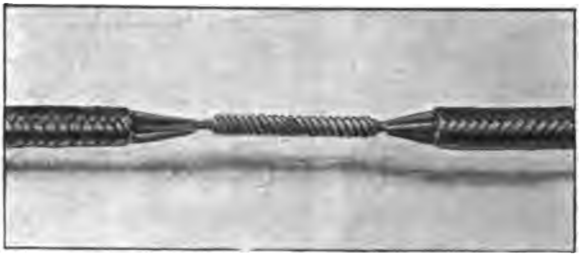


FIG. 3.

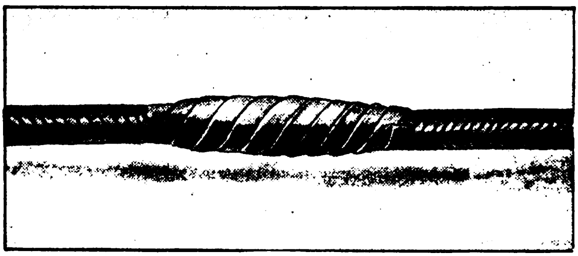


FIG. 4.

"The mode of 'marrying' the conductors is made plain in Fig. 2. The six strands of each cable pass alternately through those of the other. The conductors are pressed together end to end, and the strands of one cable are twisted round the conductor of the other, and *vice versâ*. Care should be taken in twisting these to follow the same direction of turn as the body of the stranding in the conductor. The joint has now reached the stage shown in Fig. 3, and is ready for soldering. Resin only should be used as a flux, and the solder should be allowed to thoroughly permeate the joint. Rubber solution is next applied, and this should be rubbed evenly, in not too large a quantity, all over the surface of the joint, and of the exposed inner insulation. Pure rubber strip is now tightly bound in two layers throughout the whole length of the joint. A small allowance of india-rubber solution should be again applied to securely amalgamate the layers of tape. One or two layers of prepared or black tape are bound over all, and these again should receive an application of solution, the latter being well rubbed in. The joint is then finished, and Fig. 4 affords a good illustration of its appearance.

"Joints in single and 3-strand wire are usually made in the ordinary 'twist' form, and then soldered and insulated as described above. 19, 37 and sometimes 61-strand cable is 'married' in the manner above described, the whole of the core being cut out, leaving only the outer strands. The cores are carefully butted tightly together, and the joint

is proceeded with as above. Binding wire will be found useful in these cases for holding the large number of strands in place while the joint is made.

"In the case of a branch wire or cable being required to be tapped on to another of larger dimensions, there are two modes of joints in general use. One is on the T principle, and consists in tapping the branch conductor direct on to the main cable at the point where the off-shoot is required. The second is the parallel method, and is preferable in most cases, from being easier to insulate and other reasons. In making a parallel branch connection, the cable is stripped for about two inches at a point several inches further back than that at which the actual branch wire is desired to emanate. The end of the smaller conductor is stripped and cleaned for 6 or 8 inches and thrust between the strands of the cable. The latter is pinched tightly over the branch conductor, which is then wound strand by strand and tightened round the exposed portion of the cable. The insulated part of the branch wire is kept close to and parallel with the main cable until the point is reached where it is wished to take the direction of the tapping. It will be seen that this method makes it an exceedingly easy matter to arrange for the tapping to leave the main at the exact point required; and the actual joint, moreover, does not immediately face the outlet opening in the casing, as is the case where the direct T system is adopted.

"The insulation of the parallel branch joint is

carried out in the ordinary way, care being taken to tape the insulated parts of main and branch conductors tightly together, and to see that the space between them is amply filled with good insulating material."

The following instructions are issued by the India-rubber, Gutta-percha and Telegraph Works Co., Ltd., for making joints in 19-strand and 37-strand cables :—

"For a 19-strand cable the conductor should be bared to a suitable length, and a small binder tied round the ends next to the rubber to keep the strand in place. The 12 outside wires should then be unstranded and turned back. The central 7-strand should then be soldered up and jointed as a solid conductor. To joint the 12 wires over this, every alternate wire should be cut off short, and the two sets of 12 married, that is, the long wire from the one end jointed to the short wire on the other, and so on round the central strand; thus half the joints on the single wires will be on the one side of the joint in the central strand, the other half being on the other side. The joints in these single wires need not be scarfed, but only butted together at each end of the joint, where the long and short wires are soldered together, a narrow whipping of binding wire should be put on at each end and soldered, the whole being then filed down smooth.

"For a 37-strand cable the same method is followed out, with the addition that the 18 wires surrounding the 19-strand joint are married in the same way."

In certain cases, more especially in damp situations, it is advisable to vulcanize the joints so that the insulation throughout is homogeneous. The various cable manufacturers have different methods of carrying out the vulcanizing of cables, and special insulating materials are sold for making vulcanized joints. Speaking generally, the process consists in heating the insulated joint to a temperature of nearly 300° Fahr., and maintaining this temperature for about half an hour.

The following instructions for vulcanizing joints are issued by the India-rubber, Gutta-percha and Telegraph Works Co., Ltd.:—

"When the conductor joint is finished, the rubber should be carefully trimmed and cut with as long a bevel as possible, according to the thickness of the rubber, the copper conductor and the bevelled ends should then be rubbed with pure benzole, and slightly heated with a spirit-lamp. The conductor and the bevel edges of the rubber should then be lapped with a pure rubber strip laid on as tightly as possible in one or two layers, according to size; this pure rubber should then be covered with special rubber solution, rubbed in so as to exclude air as much as possible; the joint should then stand until thoroughly dry. When the solution is sufficiently dry, and will not adhere to the fingers, the rubber strip should then be lapped on spirally, forming an uniform covering over the first coat of pure rubber, care being taken, by lapping tightly and evenly, to exclude all air.

This rubber should be put on in two or more layers, until the diameter is equal to that of the original insulation, and over this a layer of tape strip should then be applied, the whole joint so made slightly exceeding in diameter that of the original insulation. When so completed, the next process is that of vulcanization. To do this it is necessary to cover the joint with special sheeting cut to the whole width of the joint and firmly rolled round it, making a longitudinal seam, binding the sheeting overall by a strong cotton selvedge tape applied spirally, and as tightly as possible by hand. The sheeting thus will serve as a mould to keep the joint together during the process. The joint should then be fixed in the 'cure' (a cast-iron box) and the cover bolted on, to prevent damage to the original insulation, and to make the box tight, the insulation on each side of the joint, and at the proper distance to fit the cure, should be lapped with two or more coats of tape to cover the original insulation down to the point of junction. When the cure has thus been made tight, molten sulphur compound, previously melted in a suitable pot, should be poured into the cure round the joint, through the small hole in the top of the cure, and a suitable thermometer afterwards inserted in this hole to enable the temperature of the sulphur compound to be noted. This temperature should be kept as constant as possible between 290° and 300° Fahr. by means of a spirit-lamp.

"After the joint has been kept at the full tempera-

ture for about half an hour, the molten sulphur is run out, and the cure cover unbolted. The joint should then be taken out, the wrappings stripped off, and it will then be found to be vulcanized. A rough test of the degree of vulcanization may be made by trying with the thumb-nail (when the joint is cool) to indent it. If the mark of the nail remains in the rubber, or if the rubber is too hard, the joint is a failure, and should be cut out and re-made. If the joint thus examined is found to be in good order, it should be finished off by lapping overall special tapes (No. 726), extending, say, over about two inches each side of the braiding; this taping to be then painted with shellac varnish.

"When insulating with rubber the hands should be kept dry and perfectly clean. When solution is used it should only be used in small quantities, and the spirit allowed to evaporate before the whole is again covered up. The spirit used should be of the best quality, so that it evaporates quickly, and leaves little or no residue behind. Special care should be taken that the rubber applied should be brought into immediate contact with the prepared ends, and that no tapes of the original insulation, or foreign material which would conduct moisture, should intervene between the two surfaces to be joined. Unless everything used is perfectly clean, and all air excluded by careful and tight lapping, the joint may be found to have blown, even though the rubber is properly vulcanized. Special attention therefore is directed to these points.

Cure for vulcanizing joints.

"If during vulcanization the temperature should drop below 290°, the heat will require to be maintained for a longer time; say if at 280°, the cure would last for about three-quarters of an hour instead of 30 minutes; but it is important that the temperature should be kept as constant as possible between the limits of 290° and 300° Fahr."

The accompanying illustration shows a "cure" as used for vulcanizing joints for wiring work made by Messrs. W. T. Glover & Co., of Salford.

The apparatus consists of two pairs of heaters or cures (shown in the figure with handles) and four pairs of dies for accommodating cables up to 19/18s, also a thermometer registering up to 400°.

After the joints are made by the methods already described, the heaters are placed in an ordinary brazier's stove or over a fire until they attain a heat of 320° Fahr. This can be tested by inserting the thermometer in the aperture provided for the dies. If the thermometer registers over 320°, the cures must be allowed to cool. When the joint is prepared the dies should be fastened on securely, care being taken to see that they fit tightly. In order to "cure" the joint fix one set of cures on to the dies, and leave them on for 15 to 20 minutes, then replace with the second set heated as before. Small joints require 30 minutes, larger joints from 40 to 45 minutes.

Wood-casing System of Wiring.—Having described in the previous chapter the general arrangement of conductors in a building, it is necessary to enter

more fully into the details of fixing and protecting the conductors.

By far the larger proportion of buildings that are wired have wood casings fixed to protect the conductors, and although many objections have been made to this form of protection, the fact remains that it still finds favour with most electricians, and appears likely to do so in the future where the conditions are favourable to its employment.

This system may be employed with advantage in dry situations, provided it is not likely to be subjected to severe mechanical injury. It is therefore extensively used in dwelling-houses and other buildings where these conditions prevail, and in spite of the rival claims of other methods which are being strongly put forward, it will probably hold its own on account of its cheapness and the ease with which it can be fixed. It also has this great advantage, that wherever it is run on the surface, it is quite a simple matter to get access to the conductors at any point in order to fix additional lights, or to alter the position of lamps or switches.

Wood casing consists of lengths of wood with grooves separated by a central fillet to take two conductors, and when these are placed in it a capping is screwed on. American whitewood is mostly employed for this purpose, as it is not greatly affected by change of temperature, and can be obtained without knots and flaws. It also has the advantage of being cheap. The casing and capping

should be thoroughly painted inside and out with two coats of priming, and the capping fixed by screws, not nails.

The grooves should be large enough to admit of the conductors being easily drawn in and out when the capping is screwed on, and the following table gives the width of grooves to be employed for the more general sizes of conductors, assuming the insulating material to be of vulcanized rubber with the tape and braiding usually employed for 600 megohm cables:—

TABLE FOR SIZES OF CASINGS.

Size of Cable.		Width of each Groove.	Width of Casing.
3/22	7/21½	¼ inch	1½ inches
7/18	19/20	7/16 "	2¼ "
7/16	19/18	½ "	2½ "
7/14	19/16	⅝ "	3 "
19/14	37/16	¾ "	4½ "
37/14		1 "	5 "

For small casings the capping should be thicker in the centre than at the sides, and the screws fixed through to the centre fillet of wood; in sizes larger than 1¾ in. width the screws should be placed on the outsides of the grooves.

Under no conditions should casing be placed behind wet plaster or in damp places. A metallic covering of some description, such as composition

tubing or iron barrel, should be used under such circumstances, as wood absorbs moisture very readily, and may thus give rise to considerable leakage through earth connections.

Workmen who have been trained as carpenters or joiners should be employed to fix casings and fuse-boards, as this work cannot be done efficiently by the ordinary wireman or with cheap labour. In buildings where inferior labour has been employed, it is not unusual to find lengths of casing come away from the walls, bringing with them switch and ceiling rose blocks, owing to the walls being plugged inefficiently, so that when changes of temperature occur the plugs come out and the casings fall.

In order to avoid the dangers arising from short circuiting, great care should be taken that both positive and negative conductors should not be placed in the same groove in casings. Many engineers will not allow even two conductors of the same polarity to be placed in the same groove, although there may be no difference of potential between them. We consider, however, that "bunching" of conductors, as it is termed, in the same groove should be allowed, provided they are of the same polarity, for in this case no short circuiting can occur should the wires come in contact with one another. From an economical point of view it is advantageous to put several conductors in a groove, as the cost of labour is lessened, and in addition to this the mechanical strength of a larger

casing containing many conductors is greater than that of a number of smaller casings laid side by side.

It must be remembered that that portion of a conductor between a lamp and its switch may become either positive or negative according to the position of the switch; that is, whether it is turned off or on. Thus, in the figure, if the switch is "on," the length of conductor between *A* and *B* is negative; but when it is "off," the connection to the negative source is broken and it becomes positive, as the connection to the positive source is still intact through the lamp, and a voltmeter connected across the terminals of the switch when in this position would register the voltage of the installation. It is necessary therefore when "bunching" to remember that conductors between lamps and their switches may be either positive or negative, and should not therefore, theoretically, be placed in the same grooves, although the worst that could happen, should the wires come in contact, would not be a short circuit, but merely the connection of two or more circuits in such a way that each switch would not act independently of the others.

In order to simplify the wiring of houses, it is an excellent practice to employ cables of different colours for conductors of opposite polarity. Red and black are the colours generally used. It is then easy to arrange that all the switch wires shall be on one pole, and when testing for faults from the main switches it is easier to localize the faults.

When fixing the fuse-boxes, a description of which will be given later, the casings should be taken right into the boxes and plenty of room allowed for the wires, so that the positive and negative wires cannot come in contact with one another behind the insulating panels. For this reason the insulating slabs should be well packed away from the walls, and all connections made in front of the boards. Badly designed fuse-boards are frequently

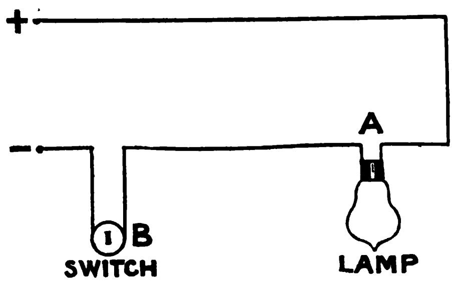


Diagram showing voltage on switch terminals.

a source of trouble, owing to the wires behind them being pressed together and bent at sharp angles.

Cleats.—In many mills and factories where power is available for electric light purposes, and cheapness is an object, the conductors may be fixed by means of wooden cleats, thus dispensing altogether with wood casing. This method has much to recommend it, provided always the fire risk is not a hazardous one and the insurance companies will pass the

installation. The conductors can be very easily fixed in this manner and the labour bill much reduced. The cleats should not be used, however, unless the conditions are such that the conductors are not liable to injury. In cases where it is proposed to employ them, leave should first be obtained from the fire insurance companies interested. Teak or some hard wood is used as the material from which they are made, and the distance between the conductors must never be less than 1½ inches.

CHAPTER V

Metal Tube and Concentric Systems of Wiring

IN these systems the cables, instead of being protected by wood casing, are drawn into ordinary tubes made either of iron or brass. The tube forms an excellent mechanical protection as it is waterproof and nails and screws cannot pierce it, but it is more expensive in first cost than casing, and when once it is fixed it is not easy to alter the position of the lights. At the present time iron barrel is more largely used than any other kind of tubing, and it can with advantage be employed in installations where the expense of wiring is not a first consideration, and nothing can be more suitable in buildings where it is necessary to have the wiring put in during the early stages of erection. In these cases the iron barrel can be fixed, and the wires drawn in afterwards by means of cords left for the purpose.

Instead of making joints in the tubing in the usual manner by T-pieces, special junction boxes

are provided, so that the cables can be drawn in in sections and the joints made in these boxes. The illustration shows a usual form of junction box with a lid, which is fixed with screws. The joints in these boxes are sometimes made in the ordinary manner already described, and sometimes by means of screwed clamps insulated from the metal of the box, and more frequently perhaps, by means of a grooved metal button resting on a porcelain in-

Junction box and lid.

sulator, in which case the ends of the conductors are soldered into the grooves of the button, and an insulating disc placed over the joint to prevent it making contact with the lid.

In new buildings many contractors put in the iron tubing before the plastering has been begun, and the conductors can then be drawn in after the decorations have been completed.

With long vertical runs of iron barrel (such as

are frequently used up lift and air shafts) the whole weight of the cables may press against the edge of the barrel at the top and chafe through the insulation. Precautions must be taken to avoid this by carefully fixing a good insulating material between the cables and the edge of the tube.

Where the iron barrels enter the fuse-boxes, nuts and washers must be placed on both sides of the outer case of the boxes to make the joints water-tight, and wherever possible the bends of the barrel should be made as easy as possible.

It is usual to draw both positive and negative conductors into the same tube, and many engineers consider the mechanical protection so good that they allow the use of comparatively lightly insulated conductors, as these are, under the circumstances, quite as serviceable as those of higher insulation, provided always that sufficient care has been taken in drawing in the conductors in such a manner that mechanical abrasions are avoided.

An objection sometimes made to the use of iron barrel is that moisture condensing in the interior may impair the insulation of the cables, and to avoid this, and at the same time provide a smooth inner surface free from burrs and projections, an insulated lining is manufactured by some firms consisting of wood or special insulating material. The expense of using tubing of this description is considerable, and it is doubtful for this reason if it will come into very extensive use.

A new system of steel tubing has lately been

introduced, known as the "simplex" steel conduit. This tubing is much cheaper in first cost than any other, and at the same time easier to fix; it is therefore commanding a large sale.

The tubes are formed of thin steel covered with a coating of enamel inside and out to prevent rust, and at the same time present an insulated surface to the cables. The following table gives the sizes in which the tubes are made, also the thickness of the metal and the weight per 100 feet run:—

SIMPLEX TUBES.

Approximate external diameter in inches . .	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2
Exact external diam. in inches	·51	·64	·77	·88	1·01	1·25	1·5	2
Exact internal diam. in inches	·42	·54	·67	·77	·89	1·13	1·48	1·87
Weight in lbs. per 100 feet . .	19	24·5	32	43	51	84·5	101	132
Standard Wire Gauge . .	20	20	19	18	18	16	16	16

The tubes can be cut either by means of a hacksaw or by filing, and the ends after cutting should be carefully smoothed.

Fig. 1 shows a T-piece, and the method of jointing the tubes. It also shows a reducing nipple fixed into the vertical arm of the T-piece. From the sectional view it will be seen that the tubes fit closely into the T-piece, and abut against a shoulder

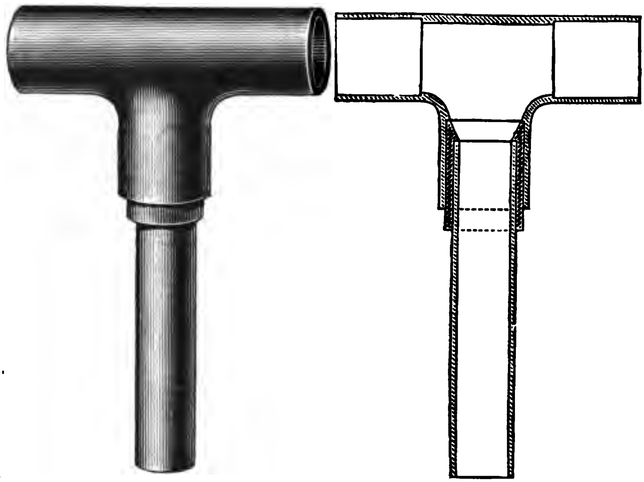


Fig. 1.

Fig. 2.

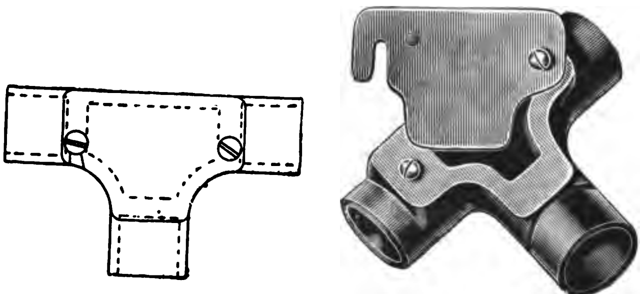


Fig. 3.

made for the purpose; no fitting or screwing is

Fig. 4.

Fig. 5.

required, nor is the sectional area of the passage

reduced at the joint; similarly, the reducing nipple is provided with a shoulder on the inside, so that the smaller tube can be pushed up against it.

Fig. 2 shows what is called an inspection bend; it is provided with a lid in order that joints can be made and inspected at any time if necessary.

Fig. 6.

Fig. 3 shows an inspection T-piece made on the same lines.

Junction boxes are made to suit the various combinations required for wiring purposes, and different forms of these are shown in Figs. 4, 5, and 6.

It cannot be said that this system of tubing is absolutely water-tight; it is very nearly so, however, and might well be employed in any situation under cover.

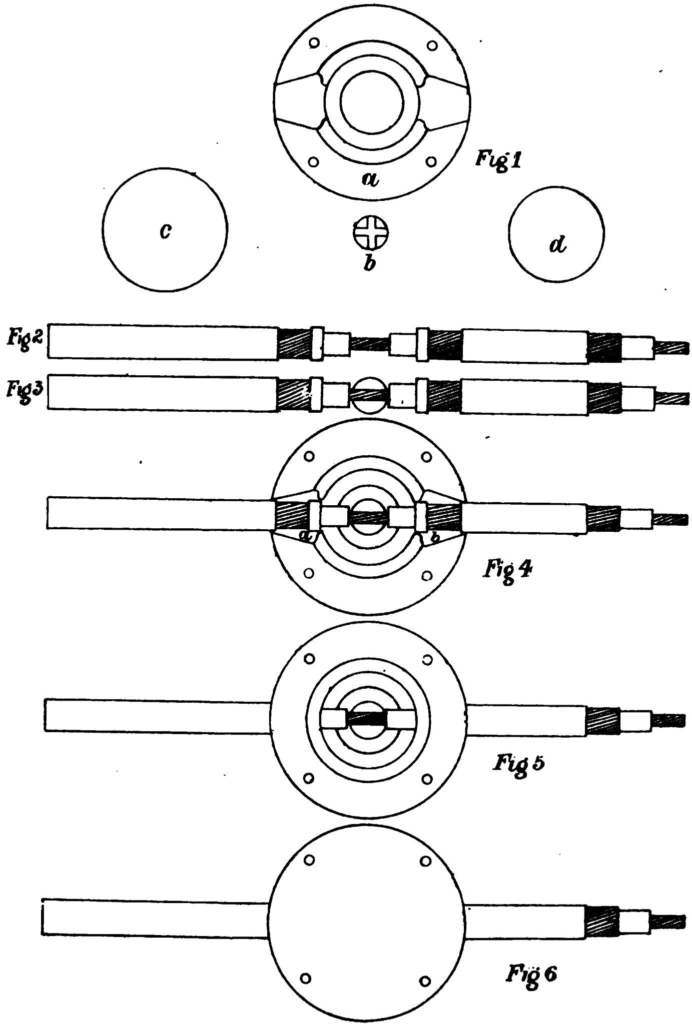
To a certain extent it is possible to bend the tubes cold; this can be done by boring a hole in a piece of hard wood about 2 feet long × 2 in. × 3 in., threading this on the tube and using it as a lever to produce the desired bend. This method must not, however, be employed on tubes of greater diameter than $\frac{3}{4}$ in.

It may be mentioned that a $\frac{5}{8}$ in. tube will take four cables of 3/22, and one of $\frac{3}{4}$ in. will take no less than eight.

If the cables are drawn in after the tubes have been fixed, it must be remembered that they should not be drawn past more than two bends at a time.

Other descriptions of tubing are used, such as Muntz metal and brass tube, in which case each conductor is usually run in a separate tube; and there is also a system in which the tubes are made of compressed paper, special brass end fittings being employed for junctions and for fixing into junction boxes.

Concentric Wiring.—In systems termed concentric both the conductors are contained in one cable, only one of which, "the inner," is insulated. The other, called the "outer," consisting of stranded wires, is laid concentrically over the insulation of the inner, and forms the "earthed return," which means that no precautions are taken to insulate the outer conductor from the earth. Manufacturers of concentric apparatus employ various kinds of cables, and in some cases a metal tube is used as the earth return,



Concentric system junction box connections.

the inner conductor being drawn into it, and consisting of an ordinary vulcanized cable.

From the above it will be seen that as only one of the conductors is insulated, the difficulty of obtaining good insulation tests is much lessened; and as all switches and fuses are placed on the insulated wire only, these are made single-pole instead of double-pole, a great gain in simplicity, as every switch and fuse is something liable to get out of order, and the more these pieces of apparatus can be reduced in number the better.

In the fittings the inner conductor only is taken to the holders, the connection to the outer being made either by the metal of the fitting itself, if it is of the nature of a bracket, or else by a special copper-braided flexible cord, if the fitting is a pendant. It will thus be seen that the outer forms one complete metallic conductor throughout the system, completely enveloping the inner conductor in a water-tight manner; and since it is purposely "earthed" at convenient points it is impossible that any shock can be received from it. As regards danger from fire this system is the safest, inasmuch as any sparks or arcing due to the electric current must take place inside the outer conductor, and as the air cannot enter, the worst that could happen would be a partial melting of the cable, and this would be an impossibility with carefully arranged fuses.

The chief objections at present to the system are, first, that the cost of the materials is higher than

those used with wood-casing systems, and, secondly, supply companies using direct currents will not allow any installation "earthed" on one pole to be connected to their mains. This is owing to the fact that should an "earth" on the opposite pole be developed anywhere on the system of network (which includes in most cases many hundreds of miles of cables) short circuits would be set up and lead to serious trouble. This objection does not apply to the same extent with companies supplying alternating currents, as transformers can be employed for any special installation, and an earth on the secondary of the transformer would not be transmitted to the high tension mains. No doubt as concentric wiring comes more into vogue, as it is certain to do, the cost of the materials will be reduced.

Mr. Andrews, of Putney Bridge, Fulham, and Messrs. Mavor & Coulson have been the chief pioneers in concentric wiring. In principle their systems are the same, but in detail the developments have been carried out on different lines.

In Messrs. Mavor & Coulson's system no cable smaller than a single 14 gauge or 7/21½ is used, and for lighting these cables are used for 5 ampère circuits starting from the distributing boards. The outer conductor consists of copper strands wound spirally over the insulation, and over this a lead sheathing is drawn to make the whole water-tight. In order to protect the cable further, an armouring of galvanized iron wires can be used over the lead, but in

the majority of cases for small cables this is not necessary. All the cables used in concentric wiring are flexible, and can therefore be easily bent round corners where necessary.

Messrs. Mavor & Coulson issue the following instructions for jointing their cables :—

Instructions for Making Joints.

A. Prepare the cables as shown in Fig. 2, p. 69, as follows :—

(1) Cut away the lead sheathing and the outer conductor from a length equal to the diameter of the central chamber of the junction box.

(2) Remove the insulation to expose a sufficient length of the core to allow of the central contact button (*b* Fig. 1) being soldered to it.

(3) Remove the lead sheathing to expose the copper of the outer conductor at the points corresponding with the jointing pockets of the junction box, but leave sufficient lead sheathing projecting into the pocket to ensure its being properly jointed thereto. An annular strip of lead sheathing, one-eighth inch wide, should be left to fill the opening to the central chamber and prevent the solder flowing into it.

(4) If the outer conductor is not already tinned, the parts exposed for the jointing pocket should be carefully tinned.

B. Solder the contact tip to the inner conductor as shown in Fig. 3.

C. Lay the conductor into the junction box as shown in Fig. 4.

D. Fill the pockets (*a* and *b* Fig. 4) with solder, using resin as a flux. A heavy soldering bolt, a melting pot and small ladle, or a jointing lamp may be used (a jointing lamp is to be preferred, except for large junctions), and care must be taken to heat the junction box sufficiently to make the tinning of the jointing pockets run.

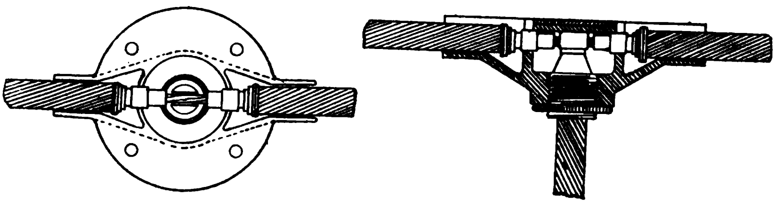


FIG. 1.

E. Lay the insulating disc (*c* Fig. 1) in the central chamber of the junction box.

F. Lay the tinned brass disc on the back of the junction box (*d* Fig. 1). in the tinned recess provided for it, and solder it to the box. The junction is then complete.

The above describes the process of making a throughway junction tapped for a fitting; and all other junctions, whether tapped for fittings or blind, are similarly effected.

When joining armoured cables, each strand of

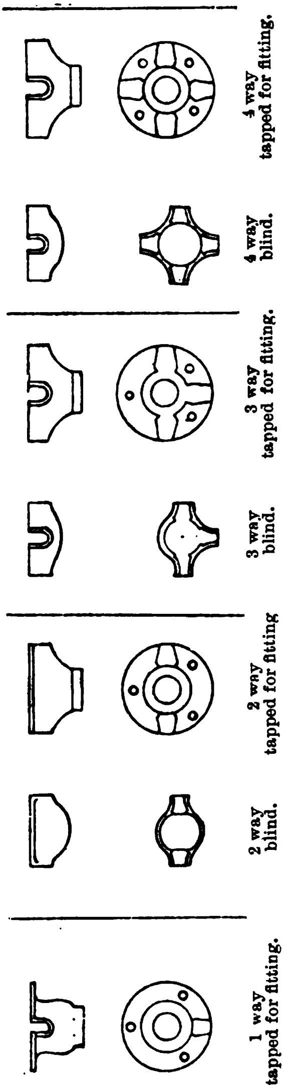


FIG. 2.

the armouring should be separately tinned before the cable is placed in the junction box.

Fig. 1 gives a plan and section of the junction box showing the insulating air space. The boxes are made of cast brass, tinned all over, to facilitate soldering, and it will be noticed that in making branches for pendants the inner conductor is not broken, and long lengths of the cable can be tapped at any desired points without cutting the inner conductor, provided switch-holders are used for the lamps, as is generally the case.

Fig. 2 shows a variety of junction boxes, in plan and elevation, used for 1, 2, 3 or 4 ways, and made so that fittings can be attached to them or otherwise.

Fig. 3 shows a main switch-board in which all

the switches are placed on the inner conductor,

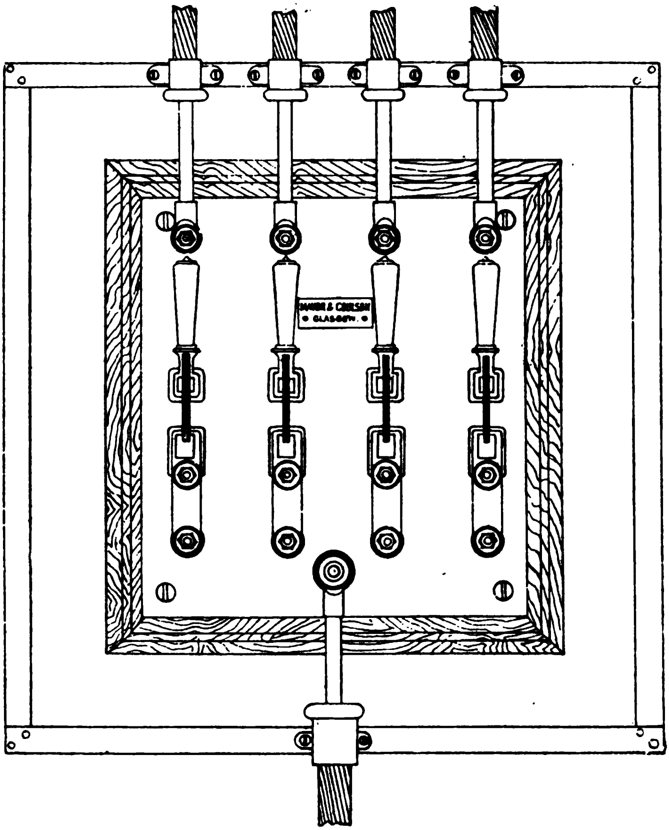


Fig. 3.—Main switch-board for concentric system.

which enters at the bottom and leaves in 4 circuits at the top. It will be noticed that the outer con-

ductors are all connected together by a rectangular copper frame.

A 4-way distribution box and pendant circuit are shown in Fig. 4. These boxes are usually made of iron. The inner conductor enters the box and is soldered to the copper bar, from which the 4 circuits are taken through the fuses. The fuse-blocks are porcelain cylinders of U section with countersunk ends. The contact tips rest in these countersinks, and are held in position by the fuse wire, which is soldered to them. The fuse-block is readily fixed in position or released by operating the milled screw shown in the illustration. The branch conductors leave the box through sockets similar to those used for the mains. The branches being of uniform section, the fuses are uniform and interchangeable.

With this system central contact incandescent lamps are used, and the lampholders consequently have a single central contact. Fig. 5 shows a double nipple to fit a junction at one end and lampholder at the other, and pendant nipples are shown in Fig. 6, the top being used for screwing into the junction box, the bottom nipple for the holder being connected to the top by means of a flexible cord. In cases where electroliers with brass tubes are employed a gimbal fitting is employed, illustrated in Fig. 7.

In order to show how the details of this system have been worked out, an illustration of a switch is given in Fig. 8. In this case the metal rim is used as the outer conductor. It is unfortunate in

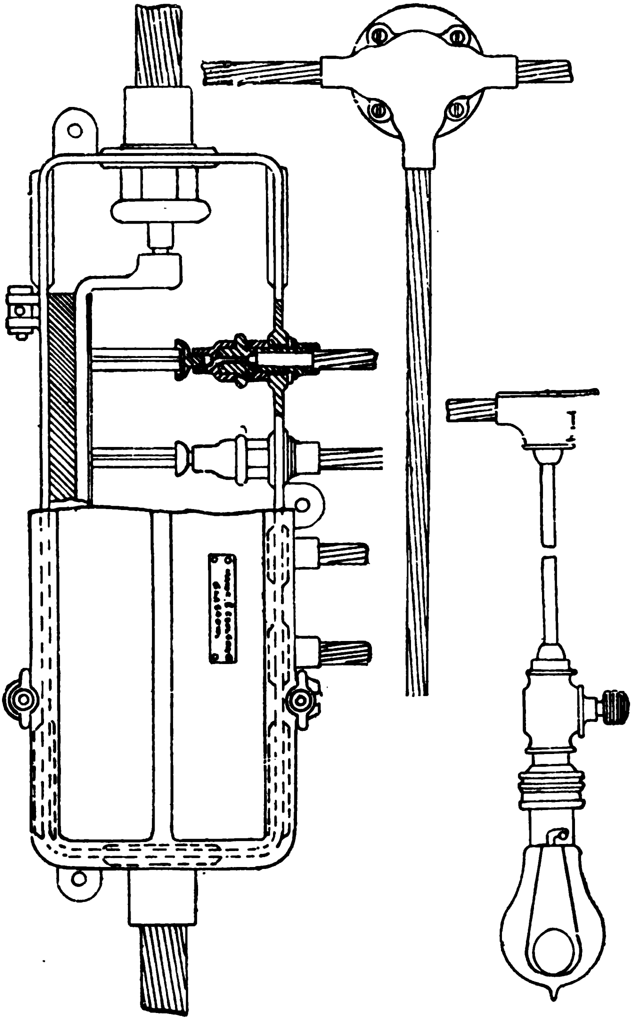


Fig. 4.—Subdistribution fuse.

this system that *both* conductors must be brought to any switch although the switch connections only require one.

In Fig. 9 the method of making the connection

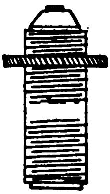


FIG. 5.
Double nipple.

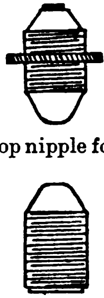


FIG. 6.—Top nipple for pendant.

Bottom nipple for pendant.

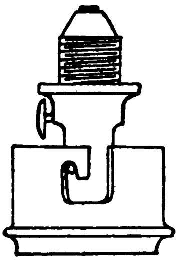


FIG. 7.
Gimbal fitting.

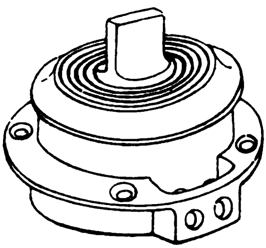


FIG. 8.—Switch.

to the terminal of a switch and earth bar is shown, and in Fig. 10 a somewhat similar arrangement is illustrated for making the connections for 2 arc lamps in series on 100 volts.

Brass tubing is now being employed to some

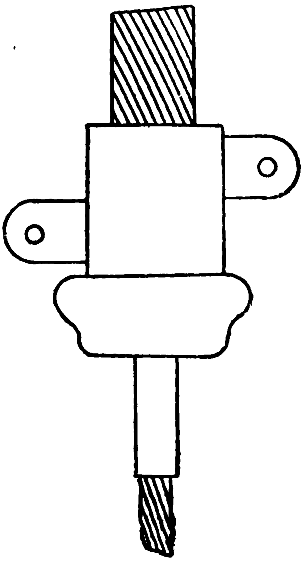


Fig. 9.—Switch-board negative bar terminals.

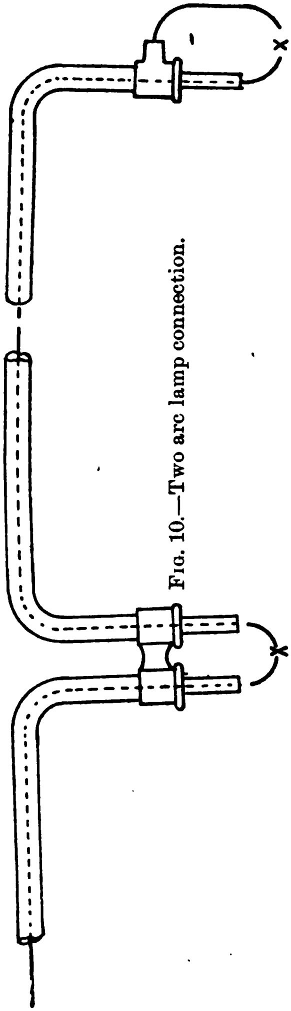


Fig. 10.—Two arc lamp connection.

extent as a protection for cables, and in many cases the tube itself is used as the return conductor, in which case junction boxes somewhat similar to those already described are used.

CHAPTER VI

Electrical Accessories

HAVING described the various systems of wiring at present in use, the various accessories, such as cut-outs, ceiling roses, switches, etc., used in installation work must be described.

Chief of these are the fuses and fuse-boards. As mentioned in a former chapter the current in any circuit, before it reaches a lamp, or group of lamps, has to pass through a piece of easily fusible metal, usually a mixture of lead and tin, and if any marked excess of current occurs the fuse at once "blows" or melts, automatically cutting off the current. Now in order to put in the right size fuse wires it is necessary to know the currents at which they will melt. Unfortunately, however, it is not an easy matter to arrive at definite rules, as a given fuse wire will melt at different currents under varying conditions; thus temperature, length of wire, size of terminals of the fuses, and contact surface, all influence to some extent the melting current of the fuses, and in addition to this oxidation and disintegration of the fuse wire play an

important part in determining how long a fuse will last.

Long lengths of a given fuse wire will melt at a certain current, within small limits, under the usual conditions of temperature; but in practice lengths of only an inch or two are used, and then the size and shape of the terminal exercise a modifying influence on the melting current, and a fuse wire that in 1 yard lengths might carry, say, 5 ampères, would in 2 inch lengths carry, perhaps, double that amount of current, as the heat developed would be carried to the terminals and the copper wires, and thus be quickly dissipated.

In order to arrive at the melting current of fuses, as actually used, direct experiments must be made with the fuse wire made up and fixed to the terminals of the fuse in which it is to be used, then known currents are passed through until the melting current is reached and recorded. It is quite useless to buy what is known as, say, 5 ampère fuse wire, then to attach it to the terminals and expect it to melt at exactly 5 ampères.

Most makers now sell fuses already made up with fuse wires adapted to currents from 5 to 100 ampères, and the melting currents are ascertained experimentally before being sent out, so that reliance can be placed on their melting with about the right currents.

Many engineers specify that fuses shall melt at about 50 % current in excess of that which the circuit will carry when fully loaded; thus a 5

ampère fuse should melt at $7\frac{1}{2}$ ampères and a 10 ampère fuse at 15 ampères.

For large main fuses it is a good rule to so arrange the size of fuse wire that, with full load current, the fuse becomes just warm to the hand, the terminals remaining cold; under these circumstances any large excess of current would at once melt the fuse.

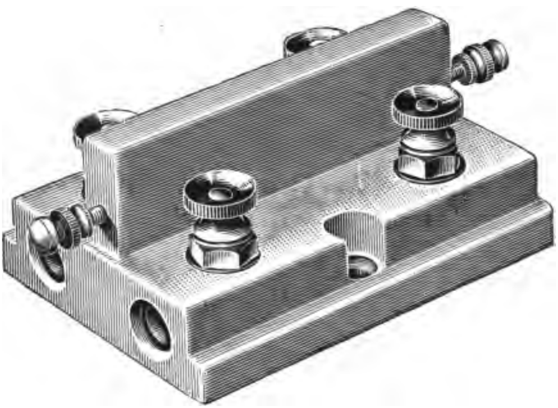


FIG. 1.

Under no condition should the terminals of a fuse be allowed to become hot, otherwise the fuse wire does not get a fair chance of dissipating its heat, and is likely to melt with too low a current, with the result that, in all probability, a copper wire will be inserted, which will not melt at all, and is a source of danger instead of a protection.

For fuses carrying large currents pure tin is

largely employed, and is not easily oxidised, and being fairly hard can withstand the pressure of the clamping screws of the fuse terminals. It may be mentioned here that large fuses are seldom made to melt at 50 % excess current. For short periods

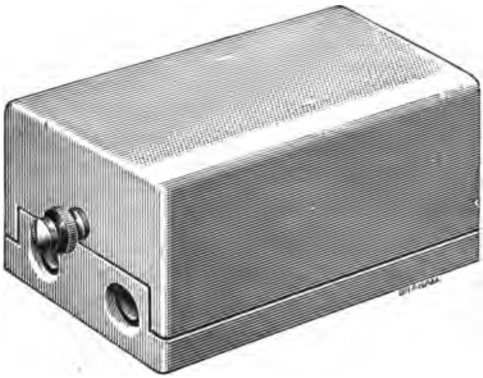


Fig. 2.

a large excess of current can always be passed through a large fuse, as a sensible period of time elapses before the temperature rises sufficiently to melt the wire.

Figs. 1 and 2 show a double-pole porcelain fuse for about 10 ampères, such as is often used for fixing direct on to casings, and Fig. 3 illustrates a larger main fuse enclosed in a cast-iron case with thimbles for the cables projecting through insulated glands in the case. This type is much to be recommended for damp situations.

In order to serve as a guide for determining ap-

proximately the sizes of fuse wires that may be employed for cut-outs, the following table gives the melting currents of various gauges of a special fuse wire as made by Messrs W. Glover & Co., Ltd., of Manchester:—

FUSIBLE WIRE FOR CUT-OUTS.

According to Mr. W. H. Preece's Table.

Approximate S.W.G.	Diameter.	Current required to fuse.
	Inch.	Ampères.
8½	0·1548	100
9·0	0·1443	90
9½	0·1334	80
10·0	0·1220	70
11·0	0·1101	60
12½	0·0975	50
13·0	0·0909	45
13½	0·0840	40
14½	0·0769	35
15·0	0·0694	30
16·0	0·0614	25
17·0	0·0529	20
19·0	0·0437	15
21·0	0·0334	10
25·0	0·0210	5
26·0	0·0181	4
28·0	0·0149	3
31·0	0·0113	2
36·0	0·0072	1

Fuses are generally grouped together and placed in cases with glass fronts, the mains being soldered to straight bars of gun-metal or copper, to which

the fusible wire for the branch circuits is connected. Figs. 4 and 5 show a very good type of fuse-box and fuse as made by Messrs. Verity, Ltd. In this the fuses are easily replaceable, and each fuse is marked with the current it has to carry; it will be noticed that the fuses are placed on each pole.

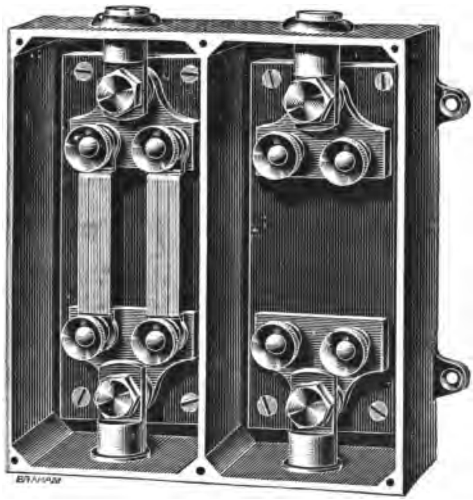


FIG. 3.

Main Switches and Fuses.—These are used to control all the lights in a building, and are usually double-pole; that is, there is a switch and fuse to each pole, the switch handles being so arranged that one movement controls both switches. The essential requisites of a good switch are, good and strong mechanical construction, ample contact surfaces and sufficient

Fig. 4.

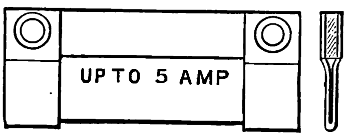


Fig. 5.

Types of Fuses.

metal for a current density of not more than 250 ampères per square inch, and a quick break. It is usual to mount the working parts either on enamel-

Fig. 1.—Switch-board with fuses.

led slate or porcelain, and if two switches are connected together by a common handle-bar each switch

should be mounted on a separate base. The handle must, of course, be insulated, in order to prevent any possibility of shocks. Figs. 1 and 2 show very good specimens of a 4-way switch-board and double-pole switch and fuse.

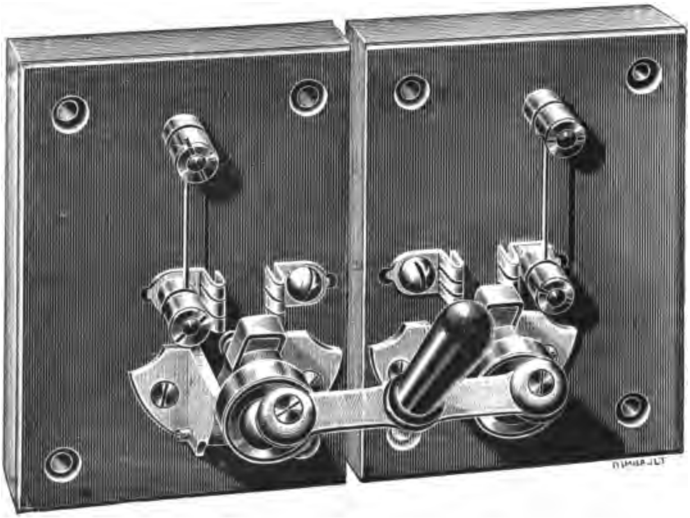


FIG. 2.—Main double-pole switch and fuse.

Branch switches for controlling single lights or small groups of lights are usually single-pole, and should be made on much the same lines as the larger switches. Fig. 3 shows the now well-known Tumler switch, and in Fig. 4 an ordinary porcelain switch is shown. In damp situations the Tumler switches should not be used, as they have metal

covers, and should one of the terminals touch the cover the handle would no longer be insulated.

FIG. 3.—Tumler switch.

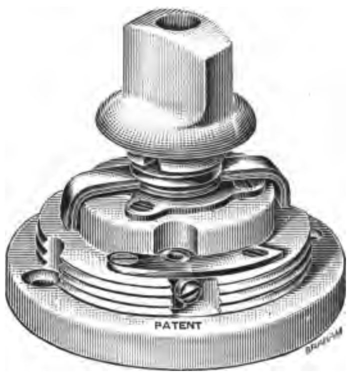


FIG. 4.—Porcelain switch.

Two-way Switches.—These are largely employed in cases where it is necessary to control a light

from two points. Fig. 5 shows diagrammatically the connections and method of employing these switches; Messrs. Verity, Ltd., make a very neat switch of the Tumler pattern for the purpose, and this is

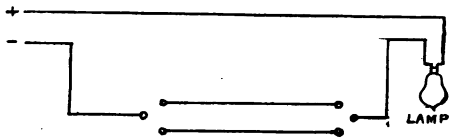


FIG. 5.—Diagram showing connections for two 2-way switches.

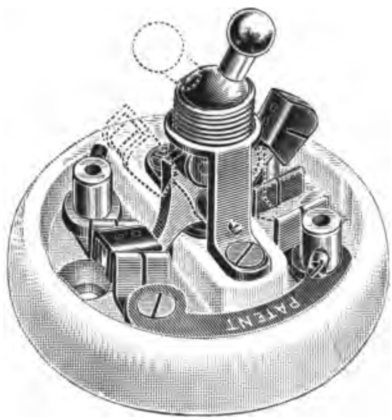


FIG. 6.—2-way switch.

illustrated in Fig. 6. There are three terminals, as in the diagrammatic sketch, but two only are seen in the figure, as the third is behind the handle.

The principle of 2-way switches may be further developed so that a light may be controlled from three

or any number of points by employing switches with four terminals. The connections in the figure are, in Fig. 1, shown for controlling a light from 4 points altogether. The arrangement looks at first sight complicated, but the two centre switches are merely

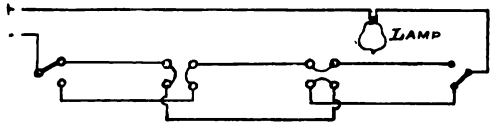


FIG. 1.—Diagram showing connections for controlling a lamp from four points.

commutators for changing the current from one wire to the other.

Ceiling roses are usually made of porcelain, and

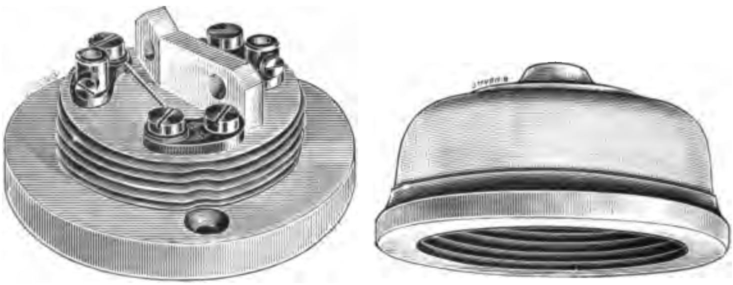


FIG. 2.—Ceiling rose and cover.

used in conjunction with ordinary pendant fittings for the purpose of making a neat and satisfactory junction between the stranded conductors and the flexible cords of the fittings. With ordinary pressures of 100 volts or less, a fuse is generally introduced; a good type is shown in Fig. 2.

It is often convenient to have an arrangement by which a flexible cord can be easily connected to the conductors for portable or standard lamps. Such an arrangement is called a wall socket, and consists of two parts, one fixed to the conductors and the other detachable. Fig. 3 shows one of the many

Fig. 3.—Wall socket.

forms of these sockets. In the fixed portion the conductors are led to two terminals, a fuse being placed on one pole, and in the detachable portion the flexible cord is attached to two prongs of metal, which engage with the two tube pieces of metal in the fixed portion when the plug is thrust into the socket. Fig. 4 shows another form of wall socket.

In order to secure good insulation and a good fixing for ceiling roses, switches and wall sockets, these pieces of apparatus are in most cases mounted

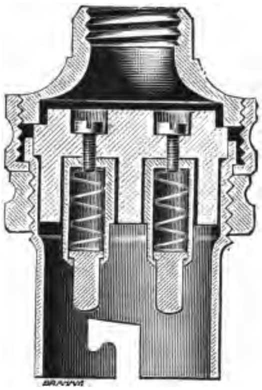
on hard wood blocks recessed at the back to allow room for the conductors.

Good lamp-holders are an important part of every installation. Each holder consists of several parts

FIG. 4.—Wall socket.

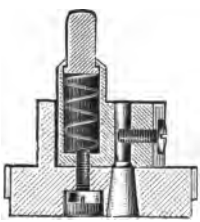
shown in the accompanying illustrations, the final contact to the lamp terminals being made by two plungers, or "bayonets," actuated by springs. The terminals are encased in porcelain, which is protected

by outer coverings of brass, screwed together by a ring, as shown. If a shade has to be fixed to the



Section of ½" bayonet lamp-holder with shade-carrier ring.

End view of holder.



Sectional view of bayonet, showing terminal for conductor.

General view of lamp-holder.

holder an additional ring is put on, called the "shade-carrier." The holder as shown is made by Verity,

Ltd., the details of the plunger being given. If the holders are to be attached to a bracket a screwed end is left, as shown, but for use with flexible cords a so-called "cord-grip" is used, by which the flexible conductors are held, so that no strain can be put on the terminals of the holder.

Other forms of holders are largely used, especially in foreign countries, but the bayonet type is at the present time almost exclusively used in England. The illustrations given are full size; smaller sizes are used for candle fittings.

Flexible cords, which are so largely used with pendants and portable lamps, are made up of a large number of very fine stranded copper wires to each conductor. For ordinary work a flexible cord for a 16-candle-power lamp should have thirty-five wires of No. 40 gauge in each conductor, and the insulation should consist of pure and vulcanized india-rubber, and a protecting covering of silk or cotton. The public cannot be too strongly cautioned against using cheap flexible cords, of which vast quantities are imported from abroad. Unless they are thoroughly well made they are a source of danger, as the two cords are twisted together, and it is easy for the two conductors to come together if the insulation is in any way inferior. Particular attention should be paid to flexible cords when pressures of 200 volts and over are used.

Wiring Fittings.—It is a very important matter to have all electric light fittings properly wired. Earth connections and short circuits are of daily

occurrence in fittings which may be excellent from an artistic point of view, but are not properly adapted for electric light purposes, and it is often surprising to see how badly the wiring of fittings is done by the makers of the fittings themselves. In the manufacture of fittings far too little attention is paid to making adequate provision for drawing in the wires, and in many cases it is impossible to get them through the tubes without injuring the insulation. The two chief essentials for good wiring are (1) that no roughness or burrs should be left in the tubes to cause abrasion, and (2) that the tubes should be of sufficient diameter to take the wires without undue crushing.

In wiring ordinary brackets the cables from the walls should be left long enough to reach the holders of the fittings so that jointing is unnecessary. Now in order to arrange for, say, two cables of 3/22 to be pushed through the bracket tube easily, the internal diameter should be about $\frac{1}{2}$-inch. If 3/8 tube is used, and the shape of the bracket is curved, it may be necessary to use either a flexible cord, or a specially made cable of small diameter, and in either case joints have to be made which have to be stowed away at the base of the fitting, and are frequently injured during the fixing of the fitting.

When fittings are adapted for electric light purposes it is often impossible to avoid the use of flexible cords, and whenever these cords pass through metal in which holes have to be drilled, an ebonite bush

should be placed in the hole to prevent any chance of short circuiting.

When wiring chandeliers with flexible cords, the connection to the conductors should be made if possible by means of a ceiling rose, and in no case should flexible cord be taken through the plaster of a ceiling without adequate protection.

On no account whatever must gas-fittings be adapted for electric light purposes when connected to the gas mains; any connection between the conductors and the fitting would at once cause a direct earth connection, which would lead to trouble of a serious nature. In all such cases the gas supply must be cut off entirely from the fitting, which must itself be insulated, either by a hard wood block or other arrangements designed for the purpose.

In many fittings, such as large chandeliers, groups of candle fittings have to be wired. In order to avoid joints in the conductors the connections can be made by running the wires to the terminal of one holder, and then connecting the holder next by means of wires taken from the terminals of the first holder; this is known as "looping" from holder to holder. Difficulties arise sometimes in cases where small lamps must be used and the pressure is high, say 200 volts; for small lamps cannot yet be made satisfactorily to withstand pressures of 200 volts. In such cases two or more lamps must be run in series. Suppose, for instance, it were necessary to wire a 7-light candlestick, the pressure being 200 volts; it

FIG. 1.

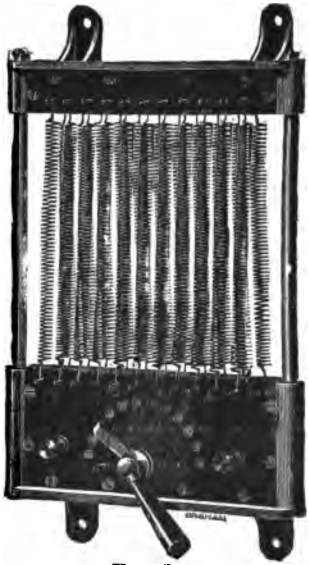


FIG. 2.

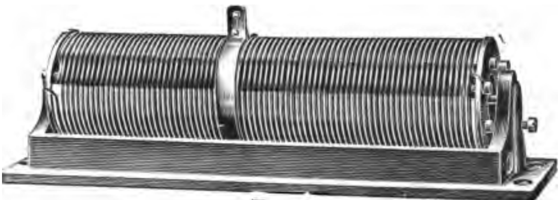


FIG. 3.

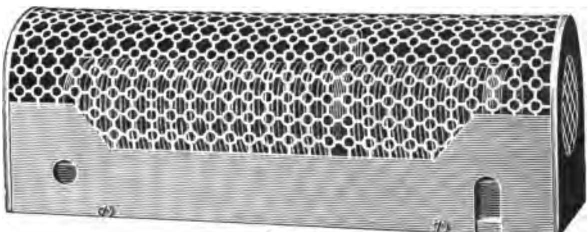


FIG. 4.

RESISTANCES.

would be advisable to use one series of three 66-volt lamps, and two series of two 100-volt lamps. This is a somewhat awkward combination, but until 200-volt lamps can be obtained in all sizes and candle-powers, combinations of this description have sometimes to be used.

When motors or arc lamps are fixed, great care must be taken to so arrange the resistances that they cannot give rise to a fire; they must be well insulated from earth, and should be preferably enclosed. Figs. 1, 2 and 3 show different kinds of resistances in use at the present time. Two of these are arranged to work with handles to cut the resistance in or out, and one has a movable ring contact. This is a usual form for arc lamps, as the contact is not likely to be moved when once it has been set for the right current.

Employment of 200 *Volts Pressure.*—Many of the large supply companies are now supplying current at 200 volts pressure instead of 100 volts as before; and in order to deal satisfactorily with the increased pressure it has been found advisable to make a few alterations in the designs of switches and fuses. Such alterations are not absolutely necessary, provided the designs were good for 100 volts, and generally speaking it may be stated here that any installation properly wired for 100 volts will stand the increased pressure, and work satisfactorily without any alteration to the wiring beyond changing the lamps and putting in fuses of half the capacity in ampères, as it must be remembered that, as the

pressure is doubled, the quantity of current consumed is one half. It must be remembered, however, that should a short circuit occur with 200 volts, the effects are likely to be more dangerous than if 100 volts are used. For this reason modifications are made in the designs of the fuse-boards: the distance between the terminals is increased,

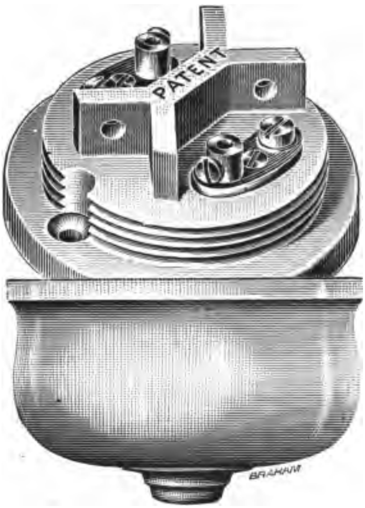


Fig. 5.—High tension ceiling rose.

and in order to avoid anything in the shape of a permanent arc (which might easily be set up with a pressure of 200 volts) a ridge of insulating material is put between the terminals of the fuses, and the fusible wire bent over this; then, in case a short circuit occurs, an arc cannot be maintained because

the direct line between the terminals is interrupted by the insulating ridge. Again, in order to prevent the harm due to sudden expansion of the air when a fuse melts, it has been found advisable to ventilate all fuse-boxes, thus allowing a passage for the air. In order to illustrate the insulating ridge above referred to, a ceiling rose is given in Fig. 5, showing the method employed for avoiding permanent arcs. As it is somewhat difficult to ventilate ceiling roses and wall sockets and switches with fuses, *no fuses at all should be placed* in these pieces of apparatus; all fuses are then confined to the fuse-boards, where there is plenty of space and ventilation.

Many engineers advise an increased break for use with 200 volts, and with heavy currents this is no doubt advisable, but with small switches for two or three incandescent lamps it is hardly necessary, as the currents are very small.

CHAPTER VII

Testing

WHEN the wiring of a building has been completed, certain tests can be applied which will, to some extent, show if the work has been carried out properly. Unfortunately there are no tests that can with certainty detect bad joints, and it frequently happens that in a badly wired house the tests come out much better than in an installation that may be considered perfect, and in which a much greater amount of care and expense has been expended. In a building that is perfectly dry, and where earth connections are not likely to occur, it is almost impossible that any test should show inferior insulation, and the wiring in such cases may work satisfactorily for an indefinite period, but should water or moisture at any time gain access to the conductors, inferior work will at once be attacked owing to electrolysis, and the wiring throughout under such circumstances is a perpetual source of danger and annoyance. Such faults, when once developed by electrolysis, are immediately detected by instruments, and can be located. In damp situations, on the other hand, it is most difficult to obtain perfect insulation tests, even if great care

has been taken with the wiring; a slight film of moisture connecting any part of the metal conductors to the earth being quite sufficient to lower the insulation resistance to such an extent that the standard fixed by the rules of the supply company is not reached, and the insulation resistance must be raised before the current connections are made.

It is impossible to insulate the wiring of a building absolutely. Under the most perfect conditions very delicate instruments could detect slight leakage across the insulating substance of the conductors; it therefore becomes necessary to fix some limit to the amount of leakage that may be allowed; or, in other words, to fix what is known as the insulation resistance to earth. As no substance in existence is a perfect insulator, the insulation resistance must depend upon the length and surface of the conductor exposed to the insulating substance, and in the case of electric cables the manufacturers use as their standard the insulation resistance per mile of conductors. In a good cable, in which the insulation consists of vulcanized rubber, the guaranteed resistance per mile will vary between 300 and 2,000 megohms per mile. The wiring, therefore, in a building, where, say, one mile of conductor is used, should have an insulation resistance of several hundred megohms. Tests, however, are generally carried out when all fittings, switches, etc., are fixed, and it is on these that moisture is likely to collect, and thus lower the insulation resistance. Under these circumstances certain em-

FIG. 1.—Ohmmeter and generator. Evershed's patent.

pirical rules for standards of insulation have been devised by supply companies and consulting engineers, and they take the form of allowing certain insulation resistances to earth in proportion to the lamps installed. According to the wiring rules of the Institution of Electrical Engineers, the standard taken is that the insulation resistance to earth, of any entire installation, be 10 megohms divided by the maximum number of ampères required for the lamps and other appliances. Thus, a 100-light

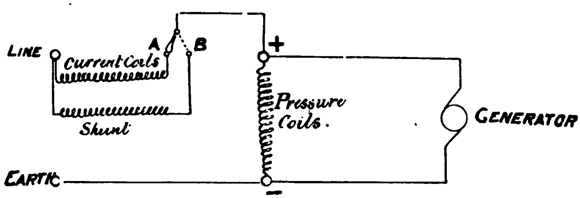


FIG. 2.—Diagrammatic sketch of connections of ohmmeter and generator.

installation, taking a maximum of 60 ampères, should have an insulation resistance to earth of $\frac{10}{60} = \cdot 16$ megohm. Tests for insulation resistance to earth are usually carried out by a set of instruments known as an ohmmeter and generator. These are illustrated in Fig. 1. The generator consists of a small dynamo turned by hand, and capable of giving a small current at 100 volts or more if necessary.

The dial of the ohmmeter is graduated in meg-

ohms and fractions of a megohm, the generator being connected to two of the four terminals, as shown in the illustration, the remaining two terminals being connected to the wiring to be tested and the "earth" (usually a gas or water pipe).

Fig. 2 shows a diagrammatic sketch of the connections inside the ohmmeter. The pointer on the dial (Fig. 1) is attached to a soft iron needle below the dial in the interior of the instrument, and is actuated by two sets of coils, called the "pressure" and "current" coils, shown in Fig. 2. The pressure coils magnetize the needle, and cause it to lie in such a position that the pointer indicates "infinity." The current coils are so arranged that if a current passes in them the needle is moved, and the pointer with it, towards zero on the dial. If now there is no resistance between the line and the earth terminals (or, in other words, if there is a "dead earth" connection) a comparatively large current will pass through the current coil, and the pointer will indicate zero; on the other hand, if the insulation between the line and the earth is above 5 megohms, the needle will scarcely be moved, and the pointer will indicate "infinity." Readings between these two can be taken indicating the insulation resistance to earth.

The instrument is so arranged that, by placing the small handle on *B* instead of *A*, such a resistance is inserted in parallel with the current coils that one-tenth of the current only passes through these coils, and the readings on the dial must be divided by 10 to get the true resistance to earth.

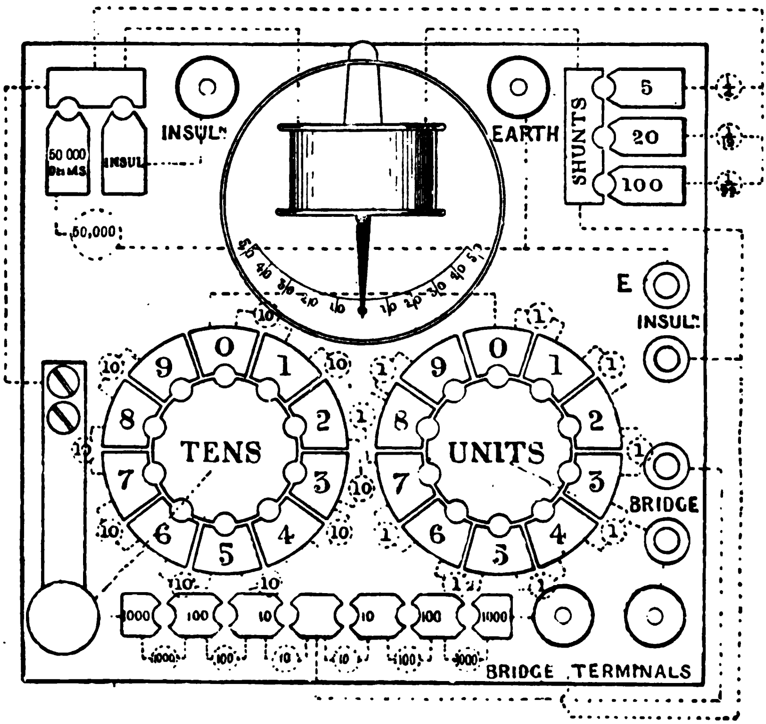
By this means the range of the readings in the instrument is much extended, and indications from 5,000 ohms to 5 megohms obtained.

These instruments are more extensively used for

FIG. 1.—Silvertown testing set.

testing the wiring of buildings than any other kind of instrument. They are light and portable, and the generator affords a simple means of obtaining a pressure as great or greater than that to which the installation will be subjected. This is very im-

portant, as defective insulation, which might withstand a pressure of a few volts, might not be able to resist a pressure of 100 volts or more. In taking the

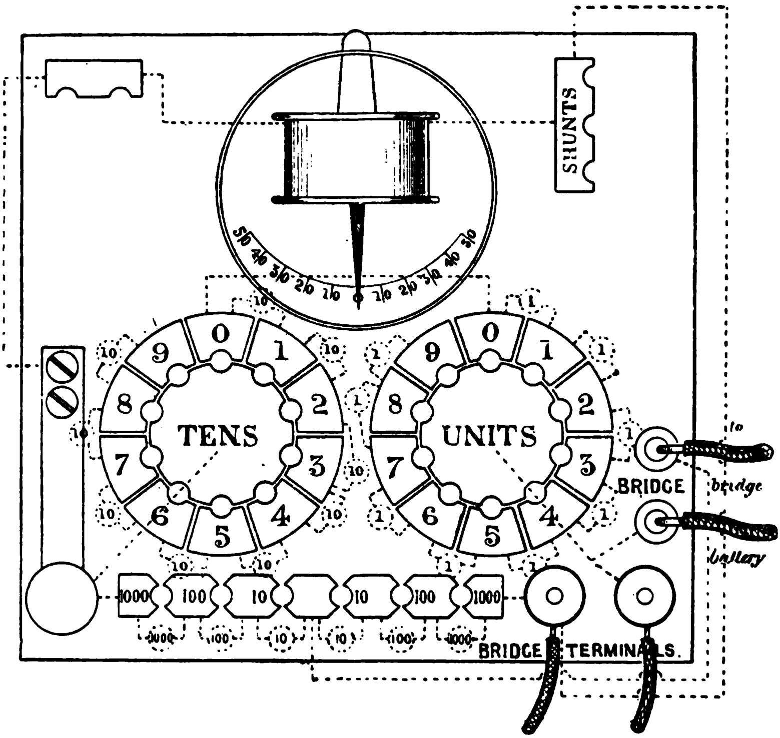


General arrangement showing all connections.
FIG. 2.

tests the readings should not be taken until the handle has been turned for a minute or two.

Another instrument that is often used for testing

purposes is known as the "Silvertown testing set," and is made by the India-rubber and Gutta-percha Company, Limited, of Silvertown. This set is shown



Connections for Testing Conductor Resistance.
FIG. 8.

in the accompanying illustrations. Fig. 1 shows the outward appearance of the testing set, and Fig. 2 a general arrangement, with the connections marked

in dotted lines. In order to obtain the necessary voltage for testing, a battery of 36 small Leclanché cells is employed, of which all or a few only can be used, according to circumstances and the nature of the tests to be taken.

The instrument is divided into two parts, one of which is for testing the resistance of conductors according to the ordinary Wheatstone bridge

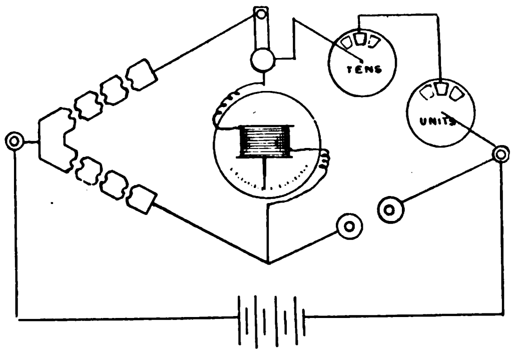
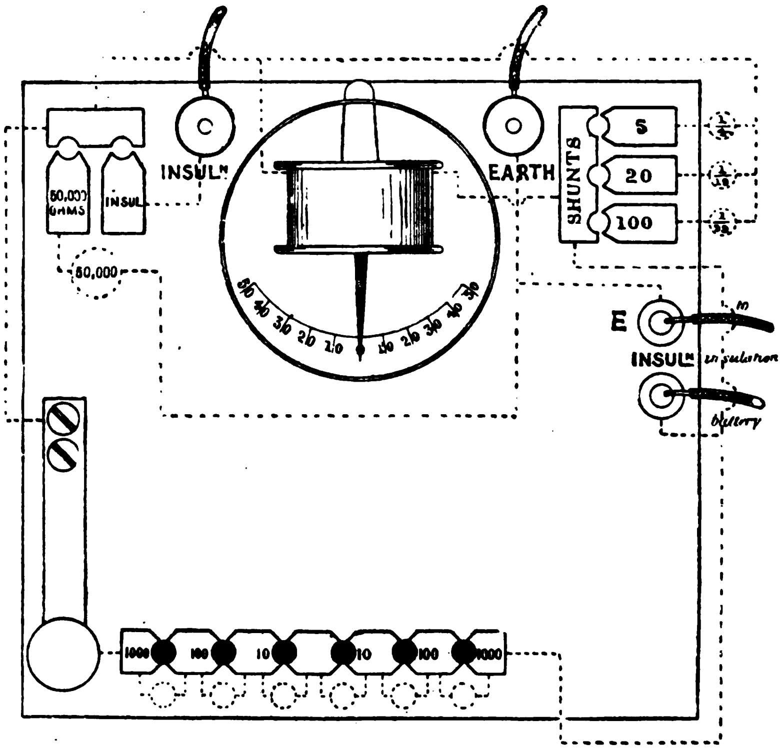


Fig. 3a.—Diagrammatic sketch showing Wheatstone bridge connections.

method, and Fig. 3 shows this part of the instrument only, with the connections marked in dotted lines. In order to make this more clear a separate diagram is given in Fig. 3a, in which the four arms of the Wheatstone bridge are shown in the form usually given in text books. For testing insulation resistances that part of the instrument shown in Fig. 4 is employed, the connections in this case also being marked with dotted lines. In order to take a

test the current from the battery is first sent through a known resistance (50,000 ohms) and the

To Conductor of Cable. *To Earth or Sheathing.*



Connections for Testing Insulation Resistance.
Fig. 4.

deflection of the galvanometer needle noted. The current is then sent through the "line" to the earth terminal, and the deflection of the needle

again noted. If this is the same as before the insulation resistance is 50,000 ohms, if greater the resistance is proportionately less, and if smaller the resistance is larger. It will be noted that the galvanometer can be "shunted," so that the readings obtained can be either 5, 10, or 100 times greater than if no shunt is used.

Certain instructions are issued with these instruments, explaining more fully their action. They are as follows:—

The battery consists of two parts: one—commonly called the bridge battery—is a set of three Leclanché cells of low resistance intended to be used in testing conductor resistances only, a purpose for which currents of electricity of sensible magnitude are required. The other part is a set of 36 small Leclanché cells having a total electro-motive force of 55 volts intended exclusively for measuring insulation resistances, or other resistances, of considerable magnitude. These cells are designed to give only very small currents of electricity, and care should be taken not to connect them inadvertently to the Wheatstone's bridge or otherwise put them on a circuit of low resistance. This battery, called the insulation battery, is subdivided into three sections of 3–15 and 39 cells, so that electro-motive forces of about 5–25 or 60 volts can be employed as may be found convenient.

The only part of the instrument which requires detailed description is the galvanometer. This consists of a coil of fine wire on a brass bobbin, in the centre of which a small magnetic needle with an aluminium pointer is hung in the same way as is usual in compasses. The pointer projects through the opening in the end of the coil, and the excursions of the needle are limited by the size of the opening to about 45° on each side of the centre. On removing the glass cover the needle on its point may be taken out by withdrawing the slide on which it is pivoted from inside the coil.

The scale, which is a scale of equal currents, is approximately a scale of tangents, and is obtained empirically by calibrating the instrument. The north end of the magnetic needle points to the left-hand side of the box when it is swinging freely in its zero position.

On the left-hand side of the box is placed the controlling magnet, and the position of this affects the sensitiveness of the galvanometer. When the north pole of the controlling magnet is uppermost, the galvanometer will be most sensitive; on turning the magnet round, so that the south pole is uppermost, the deflection of the needle due to any given current will be reduced by about 40 per cent. Generally in testing the insulation of well-insulated wires, the galvanometer is required to be as sensitive as possible, and the north pole of the controlling magnet should be at the top; but for measuring conductor resistances, for which the galvanometer is generally amply sensitive, it will be found more convenient to bring the south pole uppermost, thereby causing the galvanometer needle to oscillate more rapidly.

Besides thus affecting the sensitiveness of the galvanometer, the magnet is also used to adjust the needle to the zero in its position of rest by turning it slightly in one direction or the other.

In preparing to test, the box should be placed on a table, or some other approximately level surface in front of the electrician, he facing the magnetic east, and the controlling magnet being in a vertical position. The pointer of the galvanometer will then be found to be swinging near its zero, and may be brought exactly to it by slightly turning the controlling magnet.

If at any time the galvanometer needle should become insensitive and sluggish, it may be due to one of several causes.

It may be that the needle has become demagnetized. This can be remedied by withdrawing and remagnetizing it with an ordinary horse-shoe magnet, care being taken that this is done in the same direction as before.

It may be that some dirt has found its way into the jewel.

This may be removed with a piece of soft wood cut to a fine point.

It may be that the jewel or the needle point is injured. In this case the slide should be removed and sent with the needle and pointer to the makers for repair. This will probably have occurred either through the whole instrument having received a blow when the lid is open and the jewel resting on the needle point, or through the brass spring in the lid of the box being bent so that it no longer presses on the lifter when the lid is closed, and the needle has consequently been resting on the point while the box has been carried about.

Testing Conductor Resistance.

The method used of measuring the resistance of the conductor of the circuit under examination is that of Wheatstone's bridge.

This method is so well known and understood that it is not necessary to give here any account of the theory, only to point out the arrangement of the different parts of the testing set used in this measurement, and to indicate what coils should be plugged in the bridge for testing different resistances to the best advantage.

Fig. 3 shows only those parts of the instrument which are employed in this test, and omits the parts and their connections which relate only to insulation testing. The parts employed are the following:—

1. The adjustable resistance. This, it will be seen, consists of two sets of 9 coils each connected to circular plug commutators or dials. One set of coils has nine resistances of ten ohms each, making ninety ohms in all; the other has nine resistances of one ohm each, making nine ohms in all. If the hole marked with any number, say 5, is plugged in the ten-ohm dial, a resistance of fifty ohms is inserted between the connecting leads entering and leading away from the dial; and a similar rule applies to the one-ohm dial. Hence if the hole 6 be plugged in the tens dial and the hole 8 be plugged in the units dial, a total resistance is inserted

in the two in series of 68 ohms. The lowest resistance that can be obtained is given when both the 0 holes are plugged, when the coil resistance inserted is zero. The highest resistance is obtained by plugging the two 9 holes, when the total resistance is 99 ohms. If no plug is inserted in one or both dials, the circuit is broken and the resistance is infinity.

2. The second part of the apparatus is the double set of proportional resistances, consisting of two coils of 10 ohms each, two of 100 ohms and two of 1,000 ohms, these constituting what is known as Wheatstone's bridge. Of these only one on each side of the centre is to be unplugged for any given test, and a rule is given later on for selecting the resistances to be employed to obtain the greatest possible sensitiveness; that is to say, for selecting those coils which will give the largest deflection on the galvanometer, when the resistance plugged in the dials varies by a given error from that of the circuit under test.

3. The third part is the galvanometer, which has been already described. Its two terminals are connected to the two ends of the Wheatstone's bridge by depressing the contact key. It will be noticed that the shunt coils, with their plug commutator, are omitted from the diagram. This is done because they are not essential to the test, though they may be conveniently used when the balance of the bridge is not yet approximately correct, and very large deflections are being obtained.

4. The battery, as has been already described, consists of 3 Leclanché cells, having an electro-motive force of about 5 volts. One pole of the battery is connected in the usual way to the middle of the Wheatstone's bridge, and the other to the point where the end of the adjustable dial coils is connected to one of the terminals, to which the conductor under test is attached. The connections are made by inserting the plugs at the ends of the battery leads, in the two holes marked **BRIDGE**, and immediately this is done the current is established in the coils; the galvanometer circuit is of course not completed till the key is depressed.

5. The ends of the conductor to be tested are to be secured

under the two terminals marked **BRIDGE TERMINALS**, and in measuring low resistances care must be taken that they are very securely attached.

The test is begun by selecting the coils to be unplugged in the Wheatstone's bridge; to do this it is necessary to know approximately the value of the resistance to be measured. Generally some idea of its value can be formed, but if it is quite unknown, two coils on the bridge may be chosen at random and a preliminary measurement made. This measurement will enable the correct coils to be chosen for a further test.

The following pairs of coils are to be selected—

For resistances between 1 ohm and 10 ohms, left-hand coil, 100 ohms; right-hand coil, 10 ohms.

For resistances between 10 ohms and 100 ohms, left-hand coil, 100 ohms; right-hand coil, 100 ohms.

For resistances between 100 ohms and 1,000 ohms, left-hand coil, 100 ohms; right-hand coil, 1,000 ohms.

In all these cases coils will be employed in both dials, and a result giving two significant figures will be obtained; a third figure can always be found in measuring resistances between these limits, viz., between 1 ohm and 1,000 ohms, by observing the deflections of the galvanometer needles on both sides of the zero for different adjustments of the dial resistances near the balancing point.

For example we will suppose that the 10-ohm coil on the right-hand side of the bridge and the 100-ohm coil on the left-hand side are unplugged, and that when 45 ohms are plugged in the dials, and the key depressed, a throw of three divisions of the galvanometer needle is observed to the right; and when 46 ohms are plugged we get a throw of two divisions to the left on the galvanometer scale. It is clear that the resistance to be measured lies between 4·5 and 4·6, and is nearer to 4·6 than 4·5, as two is less than three; that is, the resistance is 4·56 ohms. As a further example, suppose 100 ohms to be unplugged on each side of the bridge, and 82 ohms to be plugged in the dials; on depressing the key, no deflection of the needle is observed. On plugging 81

ohms in the dials, a threw of six divisions to the right is obtained, and on plugging 83 ohms we get the same deflection to the left. We are then amply justified in putting the third figure in the result as 0, and the resistance to be measured is 82·0 ohms.

Resistances from ·1 ohm to 1 ohm may be measured either with the same bridge coils as are used for resistances of 1–10 ohms, viz., 10 ohms on the right side and 100 ohms on the left, but only to two significant figures, since the tens dial will be plugged at 0.

Resistances of from ·1 ohm to 1 ohm may also be measured to three figures by using the bridge coils of 1,000 on the left side and 10 on the right, and resistances from 1,000 ohms to 10,000 ohms by using the bridge coils of 10 on the left and 1,000 on the right. For both these tests, however, more battery power is required than is provided in the ordinary portable battery supplied.

For making this test attention may be called to the following points, some of which have been noticed before.

Except in testing at the extreme range of the instrument, *i.e.* quantities less than 1 ohm or greater than 1,000 ohms, the galvanometer will be found amply sensitive, and it is better to place the south end of the controlling magnet uppermost, thereby reducing the time of the oscillations of the galvanometer needle.

The battery should be in circuit as short a time as possible to avoid running down the cells, and it is well to take out one of the battery lead plugs when any alterations are being made in the plug commutators, only replacing it just before pressing the galvanometer key.

Care should be taken to connect the conductor to be tested very securely to the bridge terminals. This may be done for very large or stranded conductors, either by soldering to their ends thin brass plates with holes in them of a suitable size to go under the heads of the terminals, or the connection may be made by means of finer wires soldered to the end of the main conductor. The resistance of these must be independently ascertained and subtracted from the gross result.

Measurement of Insulation Resistance.

This is a measurement of the electrical resistance of the insulating material of a cable to the passage of a current from the inside conductor through the insulation to the lead sheathing, wet yarn, armour, or other outside conducting surface, and the inverse of the insulation resistance is the insulating conductivity, or, as is generally termed, the leakage.

This measurement is effected by a method known as that of direct deflections. It consists in passing a current from a battery through a galvanometer into a conductor of a cable whose farther end is free and disconnected, thence through the insulating material to the outside coating or earth, and so back along a temporary conductor to the other end of the battery, the deflection of the galvanometer needle produced by this current being noted. Replacing that part of the circuit which was formed by the insulating material of the cable by a standard resistance of known value, we obtain a new deflection of the galvanometer needle.

The quotient obtained by dividing the deflection produced by the current through the standard resistance by that through the cable insulation is a measure of the insulation in terms of the standard.

Thus, for example, suppose that a given battery produces on the needle of a galvanometer placed in series with the insulation of a cable in the manner described, a deflection of 10·3 divisions, and that on substituting a resistance of 1 megohm for the insulation we get 42 divisions, we find that the insulation resistance is $\frac{42}{10 \cdot 3} = 4 \cdot 1$ megohms approximately.

Fig. 4 shows only those parts of the apparatus and their connections that are used in this measurement; those which relate only to the measurement of conductor resistances being omitted.

The arrangement, it will be seen, is as follows: One pole of the battery — the battery of 39 Leclanché cells giving an E.M.F. of about 60 volts is normally employed—is connected by a conductor, ending in an ebonite-headed plug, to the

lower of the two plugged holes marked **INSULN.** Thence the current passes along a connecting wire to the block marked **SHUNTS,** and thence through the galvanometer to the upper block on the other side; we may observe in passing that these two main blocks, one on each side, are practically the terminals of the galvanometer. If a shunt is plugged, $\frac{1}{9}$th, $\frac{1}{99}$th, or $\frac{1}{999}$th only of the current passes through the galvanometer, the remainder finding its way through the corresponding shunt coil.

From the upper block on the left-hand side, the current may take two paths, according as the hole marked **INSULN.**, or that marked 50,000 ohms, is plugged; if neither is plugged, the circuit is broken, and no current can pass. This plug forms consequently a convenient make and break key. If the hole marked **INSULN.** is plugged, the current passes to the terminal marked **INSULN.**, so through the insulating covering of the cable to the outside sheathing or earth, back to the terminal marked **EARTH** and the plug-hole marked **E**, and then along the lead to the other pole of the battery. If, however, the hole marked 50,000 ohms be plugged, the current will pass through the coil of 50,000 ohms, then along a connecting wire to the plug-hole **E**, and so back to the battery.

In beginning this test the conductor of the cable, or insulated wire, or a temporary lead attached to it, is connected to the terminal of the instrument marked **INSULN.**, and another lead, connected to the outside sheathing of the cable, or the wet soil in which it lies, is attached to the terminal marked **EARTH,** care being taken that these leads are separated, and that no circuit exists between them except through the insulation of the cable.

The test then consists in—

1. Noting the deflection obtained when the 50,000-ohm hole is plugged—*i.e.*, obtaining the deflection produced by the current passing through a known resistance; this is called taking the constant of the galvanometer. It will be found in practice that with a battery of 39 cells supplied, it is necessary to use the shunt, giving a multiplying power of

20; and we may note here that the passage of the current through a galvanometer shunted thus, and then through 50,000 ohms, gives the same deflection as passing the whole current through the galvanometer not shunted and through a constant of 1,000,000 ohms. In short the deflection thus obtained is the deflection given by the battery through one megohm.

2. Transferring the plug to the hole marked **INSULN.**, and again noting the deflection obtained, the galvanometer being shunted if necessary to give a convenient reading.

On dividing the deflection on the scale obtained when taking the constant by the deflection obtained in the second part of the test, and multiplying the deflections by the shunt or shunts employed, we obtain the insulation resistance of the cable in megohms.

For example: suppose that the current from the battery when passed through a constant resistance of 50,000 ohms gave a deflection of 42 divisions on a galvanometer shunted to $\frac{1}{20}$, and that when passed through the cable insulation it gave 23 divisions with the galvanometer shunted to $\frac{1}{5}$, the insulation resistance would be $\frac{42}{23 \times 5}$ megohms $= \cdot 37$ megohm approximately.

For another example: if having found the same galvanometer constant, we obtained from the cable insulation a deflection of 10 divisions with no shunt employed, the insulation resistance of the cable would be $\frac{42}{10}$ megohms $= 4 \cdot 20$ megohms.

It will be observed that, when all the holes in the straight commutator near the front of the box are plugged, the key on the left-hand side, which is used in the bridge test as a galvanometer make and break key, becomes for the insulation test a short circuit key, and is useful for checking quickly the oscillations of the needle.

(N.B.—Although the maximum voltage of the testing battery usually employed with this Testing Set is only 60 volts, the set can be used with a testing voltage of 200 volts, as required by the Board of Trade regulations. In this case, instead of using the multiplying power of 20 as described

above, the multiplying power of 100 should be used in taking the constant—the deflection thus obtained will be the same as that which would be given by the unshunted galvanometer through a total resistance of 5 megohms, and the calculation of the resistance to be measured would then be made in exactly the same manner as described above, except that 5 megohms will be substituted for 1 megohm.)

In making this test the following points may be called attention to:—

1. Too much care cannot be taken in preparing the ends of the cable. Since we are measuring a very small current of electricity passing from the conductor to the outside sheathing, through the insulated covering, it is clear that our results will be entirely misleading if any current be allowed to pass over a dirty surface at the ends where the conductor is exposed. These ends should be looked to before testing, and in the case of india-rubber or other firm material, the section of the insulator should be pared all over with a sharp and perfectly clean knife.

2. Care should be taken not to short circuit the battery, which may easily occur in two ways. One is by allowing the two battery plugs to touch one another, when the other ends of the leads are attached to the battery terminals; and another is by allowing the lead attached to the earth terminal to touch that attached to the insulation terminal.

In both cases the battery of small cells will be for a time much overworked, and in the second the needle may become bent or demagnetized.

3. Another point that may be noticed is that in deducing the insulation resistance per statute mile from a test on any given length, the result obtained from a test on the latter is to be multiplied by the length of the piece in miles, and not divided by it.

For example, if the insulation of a cable three miles long be 15 megohms, the insulation per mile will be 15×3 or 45 megohms; or again, if the insulation of a piece of cable, whose length is 350 yards, be 7,520 megohms, the insulation per statute mile will be $\frac{7520 \times 350}{1760}$ megohms = 1,495 megohms.

CHAPTER VIII

Costs and Estimates for Wiring

TO treat the subject of the costs of wiring under the various systems in an adequate manner would be impossible within the scope of this treatise, and it is only possible to give a few hints that may serve as a guide to those who are installing the electric light. The conditions are so varied in different buildings, that, unless the details of a scheme of wiring are properly considered, it is quite impossible to say what the costs may be. One hears frequently of contractors who undertake to do the wiring of a building at so much per light (very frequently an extremely low price); but this is a very indefinite method of estimating, unless it is specified exactly what is included—it is in this respect that the public are often deceived, with the result that large sums of money have to be expended in unexpected "extras." As regards wiring only, the term of "cost per light" is misleading, since a large number of lights may be grouped together in one fitting, in which case the wiring is the same as that for one light, except as re-

gards the size of conductor employed; hence it is preferable to calculate the number of "points" of light in a building. Again, it should be specified if fittings of any kind are included in the costs, as tenders are sometimes sent in, in which it is assumed the fittings will all be "extra." Other points in tenders, such as cutting away and making good, moving of furniture, taking up of floor boards, fixing of expensive fittings, should all be carefully considered, as the cost of these items forms a considerable percentage of the costs of the whole installations. When obtaining prices for wiring work from contractors, great care should be taken in giving out the work to see that everything that can possibly be included is allowed for in the price. Some points that are likely to be omitted in a contractor's specifications are:—

(1) Cutting away and making good, painting and varnishing decorating work.

(2) Taking up carpets, removing furniture, etc.

(3) Cost of fixing fittings.

(4) The supply of lamp-holders, lamps, and shades.

(5) Removal of gas-fittings and stopping off the supply.

In the catalogues of manufacturers of fittings it is a usual practice to exclude the cost of holders, lamps, and shades, although they appear in the designs. It is far best for any one who is ignorant of the intricacies of electric lighting to employ a consulting engineer to draft a complete specification and submit it to several good contractors; the

successful one will then be obliged to follow the specification, and any extras have to be allowed by the consulting engineer.

When one is told that installations are put up at prices of 10*s.* per point, including fittings, etc., complete, it is quite certain either that the contractor is foolishly losing money, or else that very inferior materials and labour are being employed.

In any ordinary building the materials for wiring can be calculated fairly exactly, the labour costs being the most difficult to estimate. In a West-end London house the costs of materials, in a wood-casing system, may roughly be taken as follows:—

		£	*s.*	*d.*	
Cables . . .	about	0	4	0	per point.
Casing . . .	"	0	1	6	" "
Switches . . .	"	0	1	0	" "
Fuse-boards, main Switches, and Sundries . .	"	0	2	6	" "
Labour . . .	"	0	10	0	" "
Lamps . . .	"	0	1	0	" "
		£1	0	0	

The labour, it is safe to say, is *never* less than 5*s.* per point, and may be as much as £1 per point, if the difficulties are great and expensive fittings have to be fixed. It will be seen that the above prices are based on *actual cost prices to the contractor*, no

account being taken of fittings. Even if the plainest fittings are employed, the cost will be, say, 3*s*. each in addition; it therefore becomes quite apparent that electric lighting cannot be done at anything like 10*s*. per point, including fittings, and the public cannot be too careful in discriminating between good and bad work.

Competition is responsible for a great many inferior installations, and if prices are unduly cut down, bad work in some form is likely to be put in. The above approximate prices are the nett prices actually paid by the contractor for wages and materials, taking no account whatever of profit or allowances for contingencies or superintendence, and if these are to be taken into consideration, an increase of something between 30 and 50 per cent. over the whole nett costs should be allowed. Assuming, therefore, that the labour per point is about 10*s*. (a very moderate inclusive estimate in most cases), it follows that for good work, inclusive of everything, and assuming that simple fittings only are employed, a price of 30*s*. per point is not at all an extravagant price to pay for wiring. The prices above given must not be taken by any means as universally applicable, but they do apply in the case of a large number of ordinary dwelling-houses where the conditions are not especially difficult. In country house installations the costs would probably be greater than these, owing to the fact that wiremen and carpenters receive "out-money" allowances. For the same class of build-

ings the cost of concentric wiring would be about the same, but for iron barrel system the costs are greater, as the tubes are more expensive than casing, and the labour cannot well be less. For similar installations the cost per point wired should be from 10*s*. to 15*s*. more expensive than with wood casing. It is impossible to give even the approximate costs of wiring works, factories, or theatres, or, indeed, special buildings of any kind; each installation must be judged on its own merits, and it must be borne in mind that the cost of the labour determines more than anything else the total cost of the whole installation.

In drawing up specifications for wiring, a schedule of the number of lamps, points of light, switches and fittings is made, and the exact positions indicated. When this is arranged, the sizes of conductors and number of fuse-boards can be calculated. The exact conditions under which the contracts are to be carried out must be clearly specified. In order to give the reader a general idea of the usual character of a good specification for the wiring of an ordinary dwelling-house in London, of about, say, 75 lights, as carried out under a consulting engineer, the following may be taken as an example for a wood-casing installation:—

Specification for Complete Installation, including Wiring and Fixing Fittings, for 75 Lights.

General.—The whole of the work to be carried

out in accordance with the specification to the satisfaction of the consulting engineer, in accordance with the requirements of the supply company and fire insurance companies interested.

The contractors to make good all defects that may appear within twelve months from the date of completion of the contract, such defects being due to faulty material or workmanship only.

Payment.—Payment for the work to be as follows:—

80 per cent. on the certificate of the consulting engineer.

10 per cent. on the satisfactory completion.

10 ,, ,, one month after completion.

Cables.—All cables to be insulated with pure and vulcanized rubber, then taped and braided and covered with preservative compound. The insulation resistance to be at least 600 megohms per mile, at 60° Fahr., after 24 hours' immersion in water, the electromotive force used for testing being at least 200 volts.

All the conductors to be stranded and tinned, the conductivity of the copper in no case being less than that of pure copper according to Mathieson's standard; conductors of opposite polarity to be coloured red and black, and all single-pole switches to be fixed on the red conductor.

Current Density.—The ampère density of the leads must not exceed 800 ampères per square inch, assuming that every lamp is of 16 c.p. and requires 100 volts.

Casing.—The cables to be run in best American whitewood casing throughout, except behind plaster and when passing through walls and partitions, in which cases metal tubes must be employed, consisting of composition or brass tubing or iron barrel. Wherever exposed to view the casing is to have two coats of paint (to suit the decorations), and in damp situations to be shellaced inside and out.

Bunching of Cables.—Conductors of similar polarity may be placed in the same grooves of casing, but ample room must be allowed in the grooves for drawing in and out.

Distribution Boards and Main Leads.—One main double-pole switch and fuse for 50 ampères to be fixed close to the position selected for the entrance of the mains, and a pair of 19/16 to be run without any diminution in area to at least two subdistribution boards placed in convenient positions, preferably at the back of staircase. From these boards 5 ampère circuits to be run to the various lamps throughout the house.

The main-pole switch and fuses to be mounted on two enamelled slates, separated by a wood fillet. Each switch to have a quick double break of at least three inches, and the current density in the metal must not exceed 250 ampères per square inch. The slates to be mounted on hardwood battens, and to be well packed out from the wall. The whole to be enclosed in a polished teak case, with glazed front and lock and key.

In the distribution boards each pole is to be

separately mounted on enamelled slate, with a dividing strip of polished hardwood between the mains at least 1½ inches wide. Two omnibus bars to be provided, from which 5 ampère circuits are to be taken to the various lamps throughout the house, the current passing through easily replaceable fuses, each guaranteed to melt with a current of 10 ampères; the terminals of the fuses to be at least 1½ inches apart. All connections to the 5 ampère circuits to be made on the surface of the boards. Each subdistribution board to be enclosed in a polished teak box with glazed front.

In order to secure perfect insulation it is preferable to bush the holes for the screws, holding the slates to the wood battens with ebonite, both in the main switch distribution boards, so that the metal of the screws cannot come in contact with the slates.

Joints.—To be carefully made in the most approved manner and soldered with resin, at least three layers of rubber strip being put in next the conductor, and this insulation protected by a covering of two layers of strong waterproof tape.

In order to avoid joints as far as possible, the conductors should be left long enough to reach the holder of the fitting employed, wherever this can be so arranged.

No joints are to be made where the conductors are embedded behind plaster.

Switches, Wall Sockets, and Ceiling Roses.—These to be of the latest design, and fixed on polished blocks

of teak or hardwood, recessed at the back to allow space for the conductors and casing to be brought to the terminals. Where necessary rough wooden blocks must be provided, as fixing for the polished wood blocks.

Cutting away and fixing Fittings.—The tender to include all cutting away and making good, and also the cost of fixing and wiring any fittings that may be selected. It is understood that substantial wood blocks must be provided and fixed to support the weight of the heavier fittings. Where floor boards are taken up they are to be refixed with screws, so that access can be gained to the cables if necessary.

Lamp-holders, etc.—Seventy-five lamps and holders to be provided, and also the cost of ten spare lamps. The holders to be of the Edison & Swan bayonet description, and of the latest design.

Alterations and Additions.—No alteration or addition to be made without consent in writing of the consulting engineer. Any dispute that may arise during the execution of the contract shall be settled by the consulting engineer, whose decision shall be final.

Tests.—On the completion of the work, including the fixing of all fittings, the installation must be tested with a pressure of at least 100 volts, and the insulation resistance to earth of both mains together shall not be less than 3 megohms, and the insulation between mains not less than 1 megohm.

The above, with the addition of a schedule of lights and switches and their position, may be taken as a fair example of the specifications now in vogue for lighting. It will be observed that the contractor has to work under severe conditions, and if the installation is properly carried out it is worth at least from 25*s*. to 30*s*. per point, excluding the cost of fittings only, but including lamp-holders.

Similar specifications are issued on much the same lines for iron barrel installations. The kind of barrel to be employed must be carefully specified, and also the various details of the junction boxes and bends. Iron barrel "elbows" should not be allowed, as it is very difficult to draw the wires in through them.

CHAPTER IX

Regulations of Insurance and Electric Supply Companies

OWING to the rapid growth of electric supply undertakings, and the dangers inherent in installations badly arranged, fire insurance offices issue regulations that must be complied with before the fire risk is taken over. The regulations of the different companies are made out on similar lines, and the best and most comprehensive are those issued by the Phœnix Fire Office. The rules of this company are given later in this chapter in full, and should be carefully studied, as any installation completed on the lines given in them cannot fail to be a success.

The various supply companies also issue rules that must be observed before the connections to the mains are made. The rules in these cases refer more especially to the insulation tests required. As an example of the rules of a supply company those of the Westminster Electric Supply Corporation are given here.

The Institution of Electrical Engineers has also issued a series of rules embodying all that is best in the latest modern practice, and these rules touch on debatable points, such as the current density allowable in the smaller conductors and the fixing of cut-outs in ceiling roses, etc. Most of the points mentioned in these rules have already been discussed, but for purposes of reference they, too, are given here in full.

APPENDIX.

THE PHŒNIX FIRE OFFICE RULES FOR ELECTRIC LIGHT INSTALLATIONS AND ELECTRICAL POWER, COOKING, HEATING, INSTALLATIONS, ETC.

The best method of arranging an Incandescent Electric Light Installation is for the electrical mains after leaving the main switches and cut-outs to be brought to an incombustible switch-board, split between the poles. The board should have "Buss Bars" in front, to which the mains should be attached, and circuits should be taken from these buss bars, each circuit having a switch and a cut-out on the board for *each conductor*. If the circuits be large, they should be taken again to smaller boards of similar make and design to the above, and from these small 2-wire circuits not carrying more than 5 ampères when the electro-motive force of the current is 100 volts or thereabout, nor more than 2½ ampères if the electro-motive force of the current is 200 volts, should be taken with a single switch [1] and double cut-outs on the board to each. When the circuits that leave the

[1] If the consumer desires still further security he might have two switches placed up instead of one.

first main board are small, a single switch and double cut-outs for each circuit can be used, unless in certain special risks or cases.

CONDUCTORS.

Rule No. 1. Where practicable, all conductors in a building should be so placed as to be easily accessible, and capable of being thoroughly inspected whenever required.

Conductors should not be run out of sight, such as between floors and ceilings, inside roofs, behind skirting-boards, wainscoting, etc., if it can be avoided. No conductors to be run inside the roof of a theatre or other hazardous risk.

No conductor to be placed where it would be liable to injury of any kind, either mechanical or otherwise, nor where it would be subjected to a temperature that might affect the insulation upon it.

No. 2. All conductors must have sufficient sectional area, so as to allow at least 100 per cent. more electricity being safely sent through them than will ever possibly be required for the lights they are to supply.

By safety is meant that there shall be no perceptible heating of the conductors to the touch: and when proportioning their sizes, the possibility of their sectional areas getting diminished by corrosion, mechanical injury, etc., as time goes on, should never be forgotten; the importance of this cannot be overrated.

Under normal conditions for internal work, the quantity of current sent down a conductor *must not* exceed the ratio of 1,000 ampères per sectional square inch of copper, provided the amount passing through the said conductor does not exceed 100 ampères; should the amount of current exceed 100 ampères, the ratio of course must be less.

In proportioning the sizes of the conductors, the incandescent lamps must not be considered less than 16 candle-power each, unless special permission to the contrary be given.

The conductors to be of copper, the conductivity of which should not be below 98 per cent. of that of pure copper.

All conductors of a larger sectional area than No. 16 S. W. G. to be composed of strands. No conductor of less size than No. 18 S. W. G. should be used except in fittings, and in these no conductor should be less than No. 20 S. W. G.

It is as well to arrange the work when it can conveniently be done so that not more than 100 ampères pass down any single conductor.

The use of copper is not obligatory in all cases.

When insulated copper is used the copper should be "tinned" or otherwise protected from the possibility of any injurious action upon it from the insulation.

No. 3. No naked conductor, or conductors, allowed in a building.

Unless in those cases for which special permission has been obtained to use naked conductors.

No. 4. All conductors (except those for certain special risks) must be highly insulated with very substantial coats of india-rubber of the highest quality, *which must be specially prepared to last*, and which must be of approved thicknesses (or other *specially approved* equally good material (or materials) that will not too readily become plastic, that is impervious to moisture, and of lasting quality, and to use which *special permission in writing* has been obtained). With regard to the coats of india-rubber, the outer ones must be of vulcanizing india-rubber, but the ones next the metallic conductor must be of pure india-rubber (unless permission to the contrary be given), and the whole taped and properly vulcanized together, and the insulation should be further protected by strong and durable coverings, such as braided hemp and the like, which should also be so treated as to be impervious to moisture. The insulation should be as uninflammable as practicable, regard of course being had that neither its efficacy nor its durability is in any way diminished thereby, and must contain no ingredient that would injuriously affect the metallic conductor it insulates unless efficient safeguards have been taken to protect the metallic conductor from any possibility of such injury.

The insulation on a conductor must be in the form of a

homogeneous tube, and it is desirable that the india-rubber composing the tube be as thick as possible.

No material or materials will be allowed to be used under any circumstances for the purpose of insulation, except those that are approved by the Technical Adviser of the Fire Office. The composition, quality, thickness, make and resistance of the insulation of all conductors must be to his entire satisfaction.

Nothing is stated above as to the resistance required in the insulation of conductors before being placed up in a building, so many cases having occurred of insulation that has given extremely high results so far as tests are concerned before being placed up, breaking down after having been in use for a short time. What is really required is, an insulation that will last, even though its resistance may not have been originally so very high. It may be mentioned, however, that the insulation resistance of conductors before being placed up should not be less than 400 megohms per mile in dry places and 1,000 megohms per mile in damp places. The tests must be taken with an electro-motive force of not less than 400 volts after the cables have been immersed in water at 60° Fahr. for 24 hours, and with one minute's electrification.

No. 5. In non-hazardous risks the conductors, having been thoroughly well insulated, as described under Rule 4, should be enclosed in iron or other approved metal tubes, or in other approved fireproof tubes, or in substantial wood casing; if wood casing be used, the conductors must be kept apart by a continuous fillet or width of wood, and the fillet or width of wood should be at least one inch in breadth in the case of mains and principal branches, and half-inch in breadth in that of the smallest branches. The casing should be composed of sound, hard, well-seasoned wood.

No tube of any kind, or arrangement of tubes, will be allowed that is not approved by the Technical Adviser of the Fire Office. No tube will be allowed of any material that does not meet with his approval.

When a system of metal tubes is employed, the metal tube

should be earthed, except in those cases where earthing would not be desirable.

In no instances, unless special permission has been obtained to the contrary, are conductors to be run unenclosed. When permission has been obtained to run conductors unenclosed, then the mains should be kept at least from 4 to 6 inches, and the small branches at least 2 inches apart; and no conductor should be less than 2 inches from any other conductor, or conducting substance, unless special precautions against contact have been taken. When the electromotive force exceeds 220 volts, the distance the conductors in the mains and principal branches should be kept apart from each other, and from all other conducting substance, ought to be at least 6 inches, unless permission for a lesser distance be given. With regard to the small wires, the distance apart must be to the satisfaction of the Technical Adviser of the Fire Office.

When unencased conductors are allowed, they should be fastened to approved porcelain or earthenware insulators.

Where external injury is possible, care must be taken to enclose the conductors in metal or other approved fireproof tubes, or in special casings, or in such other approved manner that will tend to prevent any injury accruing to the conductors as time goes on.

In hazardous risks all conductors should be very highly insulated, and be laid in iron, steel, or other approved metal tubes, or in sound, hard, well-seasoned wood casing, thoroughly well treated with an approved fireproof paint or compound, unless wood casing is not considered desirable; or such other precautions may be required that may be considered requisite, having regard to the circumstances of the risk.

For theatres and very hazardous risks, see Rule No. 38.

In all risks, if the electro-motive force of the current used is of 200 volts, or upwards, special precautions, varying according to the electro-motive force employed and the surrounding conditions, may be required, if considered necessary.

When the current is of extremely high electro-motive force, then the conductors may have to be encased and kept apart as described in Rule No. 29, for the primary conductors carrying alternating currents to secondary generators, or be arranged in such special manner as may be decided, having regard to all the circumstances of the case and the risk.

There must be no crossing of wires in casing.

A number of conductors may be placed in a single iron or steel tube.

When alternating currents are used, conductors must not be placed separately in metal tubes.

Great care must be taken with regard to the jointing of tubes (or pipes) and also that the tubes are so arranged that they will be free inside from moisture. Where necessary they must be furnished with proper junction boxes.

No non-fireproof tube will be allowed without permission.

The interiors of metal tubes might be lined with an approved insulating compound, but this is not obligatory.

There must be no "bunching" of positive conductors together or of negative conductors together in wood casing in any hazardous risk without permission. No "bunching" will be allowed in any place or in any risk that may be deemed undesirable by the Technical Adviser of the Fire Office.

No "bunching" should be done in any risk where the E.M.F. of the current supplied is 200 volts or upwards, without permission, unless the conductors are in approved metal tubes.

When lamps are in series, the minimum distance apart of any two conductors (or portions of the circuit) must be regulated by the difference of potential between such conductors (or portions of the circuit).

The small conductors about lamp fittings cannot always comply with Rule No. 5. The work, however, in connection with them must be of a thoroughly secure character.

It is preferable that all wood casing in non-hazardous risks be treated with an approved fireproof paint or compound, in order to render it as non-inflammable as possible.

The covers of the wood casing should be screwed on; they should be screwed at the sides. The covers for large casings should be screwed at the centre as well as at the sides.

It is sometimes desirable to putty the joints of wood casing.

Conductors should never be laid in brickwork, concrete, cement, plaster or like materials, whilst the same are wet, or while they are drying, when there is any liability of the conductors or their insulation being injured thereby.

Care must be taken to ensure that any cement or putty that may be used contains no oil or other ingredient that would be injurious to the insulation of the conductors, or would in any way cause the insulation resistance to be lowered.

No 6. Flexible twin-wire should be kept as free as possible from the vicinity of inflammable materials, be very carefully protected by cut-outs; its insulation should be substantial and protected as much as possible against abrasion. Flexible twin-wire should not be in any position where it could make an earth, nor must it be hidden away. Too much attention cannot be bestowed on this rule.

All twin-wires, and the positions in which they are placed, must be to the satisfaction of the Technical Adviser of the Fire Office.

Twin-wires are not allowed in certain risks without permission.

Frequent examination of twin-wires should be made.

No. 7. All conductors in buildings passing between floors and ceilings, inside roofs, behind wainscoting, through partitions, or otherwise out of sight, must be enclosed in approved metal tubing or other approved tubing or wood casing, unless in the opinion of the Technical Adviser of the Fire Office tubing or wood casing would not be desirable. Under some circumstances the precautions with regard to hidden work will require to be special.

No conductor carrying a current of over 230 volts to be laid out of sight, between floors and ceilings, behind wainscoting, etc., without permission.

No. 8. All conductors in a building that are exposed to moisture must have thoroughly waterproof insulation, and special care to protect the conductors from damp must be taken. All casings, under similar conditions, in or about a building must also be thoroughly waterproof, and of lasting material and character. Too much care cannot be taken with regard to these matters.

When conductors are being placed in buildings during course of construction, or before the buildings are "dry," the utmost care should be taken to guard against injury to the insulation, joints, fastenings, switches, casings, etc., from the action of any damp material or materials; from neglect of these precautions much trouble has arisen in installations. Wood casings should not be used in floors or walls, etc., where they might be affected by the damp or moisture given off by the building. All work in a building, such as above described, should be "special." An electrical contractor should never be required to place up work in a building if it be not sufficiently "dry."

Wood casing inside or under roofs should be especially protected against moisture, and if casing be used it should be rendered as waterproof as possible, and all joints puttied. Metal pipes would be preferable to wood casing.

Electric work should not be placed underneath water pipes, cisterns, pavement gratings, etc., unless special precautions have been taken against moisture.

No. 9. External conductors attached to a building must, unless permission to the contrary be given, be insulated, and the insulation must be of a waterproof and durable character calculated to resist deterioration from atmospheric influences.

The insulation, method of fixing, general arrangement, etc., to be to the satisfaction of the Technical Adviser of the Fire Office.

Conductors passing over a building come under this Rule

No. 10. Conductors must never pass through party walls separating two risks, unless permission to do so has been given; and when this has been obtained, provision must be

made, so that the conductors cannot be a means whereby fire can be communicated from one risk to the other.

If conductors are carried up lifts, special precautions may in some cases be required.

No. 11. All conductors passing through the exterior walls of buildings must be insulated and enclosed in separate earthenware or approved metal tubes, or laid in a cement not injurious to the insulation, in the manner described under Rule No. 5.

The arrangement must be such as not only to prevent moisture entering, but also fire penetrating from the outside by running along the conductors.

Conductors should never enter a building through the roof without special permission.

Joints.

No. 12. When two conductors are joined together, the junction must be soldered. All joints must be most carefully made and insulated. The insulation of joints must be as perfect as possible, of a lasting character and waterproof; special care must be taken to guard against moisture in damp places.

Where conductors are run in metal tubes junction boxes should be provided for joints.

No joints should be placed in situations where they would be liable to moisture.

Joints should be highly insulated with layers of rubber strip with rubber solution between, and then layers of prepared binding tape with rubber solution between, and when possible a vulcanized rubber sleeve might be drawn over the whole.

Under certain circumstances the insulation of joints should be vulcanized.

Wherever possible, joints should not be immediately opposite to each other in wood casing.

Resin should be used when soldering.

The surface of a joint should be smooth after soldering

and have no projecting points that might tend to pierce the insulation.

Cut-outs.

No. 13. Wherever a branch is led off any conductor to supply current for one or more incandescent lamps, or for any other purpose, a short length of lead, tin, or other fusible metal or substance, must be inserted at the junction of the branch with the conductor, or as close thereto as possible; and the lead, tin, or other fusible metal or substance, must be of such section, length and nature, that if the current passing through it exceeds the normal current by 50 per cent., then it will fuse and disconnect the branch. In those circumstances where it is conveniently practicable to have cut-outs that will fuse at a less excess above the normal than 50 per cent. these must be placed in. All cut-outs should be proportioned to fuse at as small an excess above the normal as is compatible with the proper and efficient working of the lights, and be enclosed in approved fireproof boxes, when not placed upon incombustible distribution boards. Porcelain or earthenware boxes are preferable to use. Cut-out boxes must be of an approved type.

Cut-outs should not have less than a clear inch break for currents up to 100 volts pressure, nor less than 1¼″ to 1½″ for currents of from 100 to 200 volts; the break must be of such a length or so arranged that an arc could not be sustained between the terminals of the cut-out. The quantity of current passing, as well as its electro-motive force, must be taken into consideration.

When the current used is of 200 volts or upwards (especially if the current is obtained from a central station and delivered from a three or more wire system) cut-outs must not be placed in ceiling roses without permission; every branch should be protected by a cut-out on each pole.

When the normal current sent down a small wire does not reach half of the safe-carrying capacity (as described in Rule No. 2) of the said branch, then the cut-outs may be arranged

to fuse at a higher percentage than that stated in the above paragraph, provided such amount of current does not exceed 100 per cent. of the normal current of the small wire, and that the margin of safety is not lessened thereby. All principal branches, and branches having a considerable number of lights, must have cut-outs on both poles. Small branches, taken off conductors of much larger size, and the branches supplying current to fittings containing several lights should have cut-outs on both poles.

When the current is derived from a central station, or from accumulators, no branch carrying 4 ampères or upwards should be without cut-outs on both poles.

All cut-outs, including the materials of which they are composed, and the positions in which they are placed, must meet the approval of the Technical Adviser of the Fire Office; many cases having occurred of cut-outs failing to act when required, and even, sometimes, themselves being the cause of a fire. They should never be placed under floors, inside roofs, or behind wainscoting, or skirting-boards, or in wood cupboards, etc., unless special precautions are taken, and *special* permission obtained. They must be so arranged and mounted, that no danger could arise in the event of their heating or fusing.

Cut-outs should be in fireproof boxes when not on incombustible boards.

When the maximum amount of current carried by a branch or small circuit never exceeds between 4 and 5 ampères, and this branch or small circuit is provided with a cut-out on each pole, then no other cut-outs need be used between them and the lights, unless considered advisable by the Technical Adviser of the Fire Office.

By " branch " is meant any conductor issuing from another of greater sectional area.

If any conductor, by re-uniting with any other conductor, or by any other arrangement, becomes technically part of the main, it will still be considered as a branch if its sectional area is less than the conductor it issues from, and must be protected as such.

The mains themselves, both positive and negative, must be protected by cut-outs, which should be placed as near the dynamo (or source of electricity) as possible; these, like the other cut-outs, must be proportioned to fuse at as small an excess above the normal as is practicable and compatible with the efficient working of the installation. The excess above the normal must not exceed 50 per cent. without permission.

When one main of a high tension system is earthed it need not have a cut-out unless required by the Technical Adviser of the Fire Office.

In a 3-wire system the cut-out on the middle wire may be made to fuse at a greater excess of current above the normal than that above stated—it may be proportioned to fuse at 100 per cent. above the normal current.

If, however, a branch is already protected by cut-outs on the mains, or on a superior branch, then it may not be necessary to again protect it by other cut-outs, unless required to do so by the Technical Adviser of the Fire Office.

The Technical Adviser of the Fire Office may give permission, under certain circumstances, for a larger proportion of current than 50 per cent. above the normal to be carried by a cut-out.

When lights are grouped, as upon electroliers, etc., the small wires to each light cannot always have cut-outs. Care should be taken, however, that the last controlling cut-out carries as small an amount of current as practicable, and that it will act before the smallest wire runs any risk of getting unduly heated.

When an incandescent installation is arranged on the "multiple circuit" system with distributing switch and cut-out boards, the ultimate distributing circuits should carry as small an amount of current as possible—not more than from 4 to 5 ampères, and be protected by cut-outs on both poles.

With regard to arc circuits, or when incandescent lamps are arranged in series, the question as to whether fusible cut-outs, or what other kind of cut-outs, should or

should not be used, will be decided as each particular case arises; so much depending upon the arrangement of the lights and the system of lighting. When arc lights are arranged in parallel, the conductors must have cut-outs.

Should it be desired to use magnetic cut-outs, or any other kind of cut-out, in lieu of fusible ones, permission must first be obtained.

Fastenings.

No. 14. The fastenings of conductors should be composed of a non-conducting material. When permission has been given to run conductors unencased, they should be fastened to approved porcelain or earthenware insulators. When, however, metal staples are allowed to be used, a piece of india-rubber, or other approved insulating material, should be inserted between the head of the staple and the insulation of the conductor. Staples, however, ought never to be used, saddles or cleats of an approved insulating material being preferable.

In the case of external conductors, the fastenings ought always to be composed of a non-conducting material.

Earth Return.

No. 15. No earth return allowed.

Unless in those cases where special permission to the contrary has been given.

Switches.

No. 16. The house mains must have switches on both poles, and the same arrangement should be carried out as well on all the principal branches when the current is supplied from a central station or from accumulators. *The arrangement should be such that the current can be entirely switched from the lights in any portion of the building the occupier may desire.*

It should never be forgotten that turning off a single

switch, although it puts out the lights, does not turn off the electricity, which is still on, and which, under certain circumstances, may break out and fire the place. *All the principal portions of a building, therefore, should be controlled by double switches.*

When one main of a high tension system is earthed, then neither a switch nor a cut-out need be placed on it unless required by the Technical Adviser of the Fire Office.

All switches to be of such construction and make that they will not be liable after short use to get out of order and heat or fire. Their construction should also be such, that it would be impossible for them to remain in any intermediate position between full on and off.

All switches must be mounted and placed in such a secure manner that no danger can arise in the event of their heating. They must also be so mounted, that leakage of electricity from them is rendered impossible. Their rubbing surfaces should be large and their break quick; the break of the switch must be of such length that an arc could not be sustained.

Switches inside buildings, for instance, must always have an incombustible base, the insulation of which should be perfect; no metal-work carrying current should be exposed at the under side of the base; the cover should be incombustible, the switches should be kept perfectly free from moisture; the fastening screws should not come into contact with the wall, but be separately fixed into an insulating block.

With regard to switches contained in the sockets of lamps ("key sockets"), these will be allowed in those places and under those circumstances only for which permission has been obtained from the Technical Adviser of the Fire Office.

The last controlling switch should carry as small an amount of current as is conveniently practicable. The current carried by it should not, except under special circumstances, exceed 6 ampères.

No. 17. Every conductor must have a switch and a cut-out placed on it at the point of entrance into a building

when the current is generated externally; and the conductors for this purpose must be brought into the building in as perfectly secure a manner as possible to a suitable place for fixing up these switches and cut-outs in thoroughly secure and accessible positions. The switches must be so arranged that they always act together—that is, one cannot be turned on or off without the other or others.

When a building is in the occupancy of various tenants, each tenant must have double switches and double cut-outs, so placed as to enable the current to be entirely cut off from the branch that supplies his tenancy. The conductors should be brought in in a perfectly secure manner for the safe placing up of these switches and cut-outs.

A cellar may be considered as a building or part of a building from a fire point of view, unless there are circumstances that do not warrant this in the opinion of the Technical Adviser of the Fire Office.

When the source of supply is internal, then a switch and a cut-out should be placed in the dynamo-room on each conductor from the dynamo or dynamos, unless, in the opinion of the Technical Adviser of the Fire Office, the switches might be dispensed with.

Switch Boards and Distribution Boards.

No. 18. Switch boards and distribution boards should be composed of a non-conducting fireproof material. They should be in a dry and secure place and most carefully fixed and mounted, and the arrangement of the work in connection with them, especially at the back, should be such that if a fire broke out at the board the fire would have a difficulty in spreading.

The boards should be "split," *i.e.*, the positive portion separated from the negative part; the conductors should be brought to metal "buss" bars upon them, from which circuits should be taken, each circuit having a cut-out and a switch on each pole, except with regard to small circuits,

which could have a single switch on one pole, but a cut-out on both poles.

The boards and distribution boards should where possible have an incombustible frame with glass front. Under certain circumstances an oak, teak, or mahogany frame will be allowed.

When the current is generated on the premises, the switchboard and its surroundings should not only be incombustible, but there should be sufficient space at the back of the board to enable a man to comfortably get behind it at any time, unless, of course, the circumstances are such that such precautions are not warranted in the opinion of the Technical Adviser of the Fire Office.

Switch and distribution boards should not be placed on matchboarding, or on wood walls of lifts, or on wood fittings in shops containing goods.

Connections, Resistances, Lamps.

No. 19. All resistances, bare or other connections, lamps, etc., must be mounted and placed so securely that no danger could arise in the event of their heating. They must be so mounted that leakage of electricity from them is impossible. All connections must be as perfect as possible. Resistances must be securely mounted upon approved incombustible material, and placed in very secure positions, well away from all combustible materials, and they must be enclosed in approved metal cases or boxes unless permission to the contrary be given. Many fires have been caused by resistances, and it is impossible to over-rate the importance of their being securely situated.

Incandescent Lamps.

No. 20. All inflammable materials must be kept at a perfectly safe distance from incandescent lamps. Incandescent lamps may sometimes get exceedingly hot, and be the means

of causing a fire to break out. If shades be used they should be incombustible. No combustible shades should be in contact with an incandescent lamp.

Shades made of celluloid or analogous substances are not allowed.

Incandescent lamps in shop windows must be kept well away from combustible goods, and so arranged that combustible goods or materials cannot come into contact with them.

When replacing incandescent lamps care should be taken that they make proper contact, or heating may arise.

Lamp Holders, Ceiling Roses, Wall and Floor Sockets.

No. 21. All lamp holders must be incombustible, and of an approved type. It is preferable to solder the ends of flexible wires, when composed of fine strands, before attaching them to the holders.

All ceiling roses must be of an approved kind, and should be composed of an approved incombustible material and be most carefully made and fixed. Their construction should be such that no strain can be thrown on the pendant wires at their terminals in the ceiling roses. Ceiling roses should be fastened to back blocks. Ceiling roses must not contain cut-outs, without permission, when the electro-motive force of the current used is 200 volts or upwards.

No wall sockets with flexible conductors will be allowed in any place or in any risk that the Technical Adviser of the Fire Office may consider to be unadvisable. All wall sockets must be of an approved kind and composed of an approved incombustible material, and the greatest care must be exercised in fixing them. The flexible conductors should be most substantially insulated and the insulation well protected against injury.

Floor sockets are not allowed, unless special permission has been obtained.

Imitation Candles.

No. 22. Imitation candles must be incombustible, and of approved construction.

Arc Lights.

No. 23. No naked lights allowed. If arc lights are used they must be furnished with globes enclosed at the base, and so arranged at the top that no sparks or flame can escape; the globes should be of substantial make, so as not to readily break if a carbon falls or bursts. The globes must be covered round with wire netting. When arc lights are run in series, means must be taken for maintaining the constancy of the current, whatever number of lamps may be burning.

In some risks arc lamps must be completely enclosed by two separate globes, and the lamps must be of such a nature that the arc could not be sustained unless the inner globe remained intact.

Inverted arc lamps must be of an approved type, and, unless permission to the contrary be given, enclosed.

In certain risks arc lights are not allowed.

Arc globes should be enclosed at the base by a metal plate.

Electroliers.

No. 24. Electroliers should be fastened to an insulating block, which should be separately fixed to the wall or ceiling. The wiring should be of a most secure and lasting character, and carefully arranged so that it would not be liable to mechanical injury.

All electroliers and fittings must be composed of incombustible materials.

Gas Work and Electrical Work.

No. 25. Electrical work must not be situated in confined spaces containing gas pipes without proper safeguards.

Gas fittings and electric light work should be kept quite distinct from each other.

Gas fittings should never be used for the electric light unless permission to do so has first been obtained. The gas fittings would then have to be made thoroughly suitable for the purpose, and so arranged that it would be impossible for them to be the means of an "earth" being set up.

The utilization of gas fittings for the electric light may be the cause of the entire installation breaking down.

Concentric Conductors.

No. 26. Concentric conductors will be allowed under those circumstances and in those places for which permission has first been obtained and when the particular system and design proposed have been previously approved. All joints and connections must be so made that freedom from undue heating would be absolutely secured, and the outer conductor must be so securely protected that all danger from injury, corrosion, or other causes (electrical or otherwise) would be effectually prevented; the precautions taken must be such that it would be impossible for the conductors to be affected by moisture. The whole of the work must be done to the satisfaction of the Technical Adviser of the Fire Office.

The insulation resistance between the internal wire and the return of a concentric conductor before being placed up should not be less than 500 megohms per mile, for installations in which the current used is of 150 volts or thereabout; if a higher voltage is used the resistance must be greater (according to the E.M.F. employed) if required by the Technical Adviser of the Fire Office.

The internal wire should be positive, if possible. It must be insulated to the satisfaction of the Technical Adviser of the Fire Office, in accordance with Rule No. 4; the insulation must be impervious to moisture and of approved thickness. This insulation should have two approved metallic envelopes, the first one forming the return conductor, the second one forming the "guard"; these, except when the

system is earthed, must be insulated from each other in the same manner that the internal wire and the return are insulated from each other. The "guard" must be an absolutely efficient protection against mechanical injury taking place to the return conductor, and also an efficient protection against any accession of moisture to the insulation, especially when the system is earthed.

The carrying capacity of the conductors must be at least equal to the ratio of that laid down for copper in Rule No. 2; if, however, a metal other than copper be used, the specific resistance of which is greater than that of copper, then the sectional areas of the conductors must be proportionally increased.

No metal, however, will be allowed to be used for the conductors that does not meet the approval of the Technical Adviser of the Fire Office; the thickness, also, of the metallic envelopes forming the return and the "guard" must be to his satisfaction.

All switches and cut-outs must be enclosed in approved fireproof boxes.

If the system is to be earthed, then the earthing must be done to the satisfaction of the Technical Adviser of the Fire Office, but no earth connection will be allowed to a gas pipe, or to lead or compo pipes.

If any part of a concentric system be earthed, then the whole system must be concentric: unless permission to the contrary be given.

Switches and cut-outs should always act on the internal (or live) wire when the system is earthed.

The insulation resistance of the work when placed up must never be below that given in Rule No. 34 for general wiring.

When the system is earthed the tests of course will refer to the pole that is unearthed.

Electrical Power Installations, Electrical Machinery and Apparatus.

No. 27. No motor, dynamo, transformer, or any apparatus

for generating electricity to be placed in any room except the engine-room (or other approved room), in any cotton, woollen, lace, flax, jute, corn, oil, saw-mill, etc., or in any mill or factory of a like description, or in any room, or place where any hazardous manufacture or process is carried on, or in which hazardous goods are stored, or where there is risk, without certain special precautions being taken with regard to safety. Unless permission to the contrary be given by the Fire Office.

Electro motors and dynamos, etc., when in buildings such as above described and not situated in the engine-room (or other approved room) must be placed in an approved fireproof compartment, so that if the motor, etc., fired, the fire should not spread; and provision must be made that no fine dust, "fly," waste, etc., could get in, hence the compartment should not ventilate into the building but into the outside air, and the only apertures in the walls of the compartment into the building should be for the shafting and conductors. The door should be of iron or other approved fire-resisting material. The pulley should be external, but the resistances, if not in the engine-room, should be placed inside the above compartment.

With regard to metal cases, these should never be employed to cover a motor if their use would cause the motor to unduly heat, or be a source of danger through persons being liable to get shocks.

It must, however, be remembered that the fire risk of buildings varies so greatly that it is impossible to draw up hard and fast rules that shall apply to all. In some buildings it may be necessary to carry out the whole of the above precautions; in others it may not be necessary to enclose the motors at all: therefore when motors, etc., are to be placed up in buildings, inquiries should be made of the Fire Office as to the proper precautions requisite.

No motor should be placed on a wood floor in any building —the wood floor under the motor should be protected by fireproof material to the satisfaction of the Inspector of the Fire Office.

Wherever a motor or dynamo, etc., be placed, special care should be taken that it be thoroughly well insulated from earth.

Each motor should be on a separate circuit.

The arrangements with regard to each motor should be such that the current can be entirely disconnected by switches from both poles of the motor, and conductors in connection therewith, when the motor is not in use.

When motors are not enclosed in a fireproof compartment, care must be exercised that they are placed in thoroughly secure situations, and so arranged that if on fire, the fire would be prevented as far as possible from spreading; the resistances must be enclosed in a metal case or box, and be securely placed to the satisfaction of the Technical Adviser of the Fire Office.

An electrical power installation requires at least the same safeguards that apply to an electric light installation, in which the conditions of supply and the electro-motive force of the current are similar.

With regard to very small motors for fans, the question as to whether these should be enclosed or not will depend upon the nature of the risk, and the situation of the motor, etc.

Accumulators and Batteries.

No. 28. Where accumulators or primary batteries are used, the mains, both positive and negative, must have a switch and a cut-out upon each. The principal branches must also be protected in a similar manner. Small conductors taken off the mains must have cut-outs on both poles. Accumulators must be placed in a secure and approved part of the premises, and where there is thoroughly good ventilation; they should be thoroughly well insulated from earth. All work in connection with them should be thoroughly examined periodically.

The conductors, from the regulating cells of the accumu-

lators to the regulating switch-board, must be protected by cut-outs as close to the regulating cells as possible.

All wood casing and conductors, etc., should be coated with an approved compound that will protect them as much as possible from the injurious action of acid fumes or sprays.

A full description of any primary battery intended to be used must be sent to the Fire Office. Certain kinds of batteries are not allowed to be used without permission.

The current should be able to be turned off at the accumulators whenever required, and the same applies to primary batteries.

The lug connections of accumulators should be periodically examined.

Transformer System.

No. 29. When transformers (or secondary generators) are employed, and the alternating primary current is of high electro-motive force, neither the transformer nor any portion of the primary work in connection therewith should be placed inside any building, but in a fireproof chamber apart. If this cannot conveniently be done, then the fireproof chamber may be placed in an approved position inside the building, preferably against an external wall, so that the primary conductors may enter direct, and not traverse any portion of the building.

The primary conductors must be most heavily insulated with pure and vulcanized india-rubber of the highest quality, *specially prepared to last*, and of approved thicknesses (or other approved equally good material or materials), in the manner described under Rule No. 4, and they must have a very strong external covering, and the insulation resistance must be very high indeed, and to the satisfaction of the Technical Adviser of the Fire Office. The conductors must be kept at a distance of 6 to 12 inches from each other, and when they enter the transformer chamber (or inside any other building for which permission has been given) they

must be enclosed in approved separate casings, which must be of a non-conducting material, waterproof and fireproof, and these casings should be channelled into the brick or stone walls of the building; and the arrangement must be such that no leakage of electricity could take place to earth from either of the conductors, or any short circuit from one to the other.

The primary conductors must be each furnished with a switch, and these must be interlocked: they must also each have a cut-out, which will act at or below 25 per cent. above the normal current. The switches and cut-outs should be of such design and make that an arc in many of them could not be sustained—they should be placed as close as possible to the entrance of the primary conductors into the fireproof chamber.

When one main is earthed, then no switch or cut-out need be placed upon it unless required by the Technical Adviser of the Fire Office.

When permission has been given for primary conductors to enter a building before reaching the fireproof chamber, then the switch and cut-outs should be enclosed in approved fireproof boxes, and placed in accessible and secure positions outside the building, if possible. If they cannot be placed outside the building, then they must be situated in approved positions as close as possible to the entrance of the primary conductors into the building. The position of all switches must be such as to be readily accessible in order that the primary current can at once be turned off if required.

The whole of the primary work within or upon any building should be so situated and arranged that it could not be tampered or interfered with by unauthorized persons, and the arrangement should be such that, if any portion heated or fired, no damage to the building would result.

Too much attention cannot be bestowed with regard to the proper placing of all portions of the primary work, and the rendering of them safe and reliable.

A transformer should be so constructed that a leak between the primary and secondary coils is rendered impossible, and

also that it would be impossible under any circumstances for the primary current to get into the secondary conductors. All secondary work must be protected by an approved automatic apparatus (or arrangement) at or near the transformer, so that in the event of the difference of potential between either secondary conductor and the earth rising at any time above 300 volts, then the apparatus will instantly act, and cut off the current; so that it would be impossible for the electro-motive force of the current in any of the conductors in the house to be raised over 300 volts. The difference of 300 volts is mentioned, lest there should be a difficulty in providing an apparatus that would be sufficiently sensitive and reliable under a lesser increase of voltage. A safety device should act at as low an increase of the voltage as is compatible with the proper and efficient working of the lights.

It would be preferable if the secondary work in the house were also protected by an approved device, so arranged that in the event of the resistance to earth of any circuit falling below 1,000 ohms, then it would instantly act and cause the primary current to be at once cut off from the building.

Unless special permission be obtained, the primary current entering a house transformer must never exceed 3,000 volts. Should the current be generated higher than this, and reduced by means of transformers, then at each transformer, intermediate between the house transformer and the generating dynamo, there must be placed an approved automatic apparatus (or device) whereby the conductors leading from each transformer, in the direction of the house or houses to be supplied with current, can under no possible circumstances have their electro-motive force raised more than 10 per cent. above the normal. That is to say, supposing the current is generated at 10,000 volts, and converted down to 3,000 volts, then the mains carrying 3,000 volts could never be charged with electricity of a higher electro-motive force than 3,300 volts.

The secondary conductors must be highly insulated, as before described in Rule No. 4; and they should be fur-

nished with switches and cut-outs on both poles, except in the case of small branches, when single switches and single cut-outs may be used. The whole of the work should be of the very highest quality.

When transformers, primary switches, and primary cut-outs are enclosed in metal casings, these casings should be connected to earth, if it can conveniently be done.

Where the primary conductors enter and leave the double-pole switch, or enter the transformer, and it is not possible to keep them the above-mentioned distance apart, then a shorter distance may be allowed, provided they are protected to the satisfaction of the Technical Adviser of the Fire Office.

Where the secondary conductors pass out of the transformer house, they should do so separately, in approved earthenware or other fireproof tubes or casings.

Care must be taken that the earthing wire of any safety device is not attached to, or in contact with, a gas pipe.

When transformers are to be arranged in series, permission must first be obtained. The alteration of safeguards necessary will be decided as each particular case arises.

Multiple Parallel (or Multiple Series) System.

No. 30. When the "multiple parallel" (or "multiple series") system is intended to be used in any building, special permission must first be obtained in every case. The insulation of the conductors should be of the highest possible character, similar to that described in Rule No. 29, for the primary conductors when transformers are used; and all work should be of the very best possible description; and on the surface where practicable.

Every parallel (or series) must have an efficient automatic "protector" of such make and design, that if the difference of potential of that parallel should rise to 25 per cent. above the normal from any cause whatsoever, then the protector will instantly bring back the potential to the normal, or else cut out the parallel (or series). Means must also be

adopted in the dynamo-room for maintaining the constancy of the current, whatever number of lamps may be burning. A main switch must be placed in a fireproof box, in a secure and accessible position outside the buildings, when the electricity is generated externally; when the source is internal, then it must be situated in the dynamo-room. Efficient precautions must be taken to prevent earthing of the conductors either inside or outside of the premises.

By "dynamo-room" is meant any place in which the electricity is generated.

Three (or more) Wire System.

No. 31. When a building is supplied with current upon the three-wire system, the electro-motive force of the current in the building may have to be considered, from a fire point of view, equivalent to that existing between the first and last conductors of the series, notwithstanding that two conductors only are brought into the building.

Thus in a three-wire system with 100 volts pressure between each outer conductor and the central one, the electro-motive force inside a building may have to be considered as equalling 200 volts from a fire point of view. If there be 250 volts between each outer conductor and the central one, the electro-motive force may have to be considered as 500 volts.

On a three-wire system the switches placed upon the three wires must be so arranged that the three always act together.

If the system has more than three wires the electro-motive force of the current may have to be considered as depending upon the particular wires of the series brought in, and their relation to the outer ones of the series.

The whole installation should be arranged in circuits from an approved incombustible distribution board, each circuit having a switch and cut-out on each pole. The distribution board to be split.

All conductors must be protected by a cut-out on each pole.

When, however, a branch carrying not more that four to five ampères has cut-outs on both poles, the Technical Adviser of the Fire Office may give permission for no other cut-outs to be used between these and the lights.

Central Stations and Supply Conductors (Service Lines).

No. 32. When electricity is sent from a central station, each conductor must have a switch and a cut-out at its point of entrance into the premises supplied with current, and (as stated in Rule No. 17) the conductors must be brought into the buildings in as very secure a manner as possible to points suitable for placing up these switches and cut-outs in thoroughly safe and accessible positions. It is impossible to overrate the importance of taking all known precautions with regard to the prevention of fire when placing in the service lines, and coupling them up to the house wiring. The cut-outs should act at as small an excess of current above the normal current as is compatible with the proper and efficient working of the lights—the excess above the normal current should never exceed 50 per cent., unless permission to the contrary is given. The switches and cut-outs and conductors should be effectually protected against any possibility of moisture getting to them.

Where the service lines are brought into a warehouse, or buildings of like nature, containing quantities of inflammable goods, or when they are brought into any special risk, the service lines, main switches, main cut-outs, and the meter should be all enclosed in a fireproof chamber, out of which the house mains should pass in approved fireproof tubes.

The occupier must be able to turn off the electricity entirely from his premises whenever he considers it necessary. The switches should be of quick and wide break type, and

they must be so arranged that they will always act together.

Cut-outs may be placed on the service lines in a service box outside the premises, instead of at the points of entrance.

Central Stations and Accumulators.

No. 33. When currents of 200 volts or over, used from a central station (or other place) to charge accumulators, and secondary house circuits having a current of lower potential than that of the current from the central station, are taken from the accumulators, then the conductors for the house circuits should be provided with a device or arrangement by means of which their connection with the accumulators during the time these latter were being charged would be prevented.

Tests.

No. 34. In any electric light installation in which the current is continuous and has an electro-motive force of 230 volts or under, the insulation resistance both with regard to earth and between conductors over the whole installation must not get below the following:—

Installations of	12	Lights	...	1,000,000	Ohms.
„	25	„	...	500,000	„
„	50	„	...	250,000	„
„	100	„	...	125,000	„
„	500	„	...	25,000	„
„	1,000	„	...	12,500	„

When the lights are proportionate between the above numbers, then the insulation resistance should be correspondingly proportionate.

The insulation resistance of the separate circuits or branches of the installation should also be taken, and should not be less than the above table.

The minimum insulation resistance for currents of higher electro-motive force than 230 volts will be decided with regard to each instance as it arises, so much depending upon the particular circumstances of the case.

For alternating currents of similar electro-motive force the minimum insulation resistance must be twice the above number of ohms respectively.

Under normal conditions the fall of potential in the conductors in a building should not exceed two volts at the farthest points of any circuit when all the lamps are alight.

Under certain circumstances the Technical Adviser of the Fire Office may give permission for the insulation resistance to be less than that contained in the before-mentioned table.

A statement of the insulation tests must be supplied if required.

All tests should be regularly entered in a book kept for the purpose.

An isolated installation should contain an automatic device that would give a warning if a leak were set up to earth in any portion of the premises.

The pressure of the testing current should be not less than 100 volts if possible.

No. 35. Wherever electricity is supplied from a "central station" to one or more buildings, accurate insulation tests should be made at least once daily over the whole system; and a record be kept of the same. Too much attention cannot be bestowed on this matter, especially where transformers are employed, or when the multiple parallel (or multiple series) system is used.

Lightning Protection.

No. 36. All conductors from a central station, entering, or connected to, or traversing any building or buildings, should, where necessary, have an arrangement of lightning dischargers that will efficiently prevent the said conductors being a means whereby lightning can enter the above-named building or buildings.

Overhead conductors, supported by poles on roofs, will be

considered as being connected to those buildings on which the poles are situated.

In private installations where the electricity is generated at a considerable distance off, the carrying mains should have lightning dischargers.

Warehouses, Drapers' Shops and Hazardous Risks.

No. 37. Special precautions may be required to be taken with regard to electrical work in risks of the above kinds; no work should ever be commenced or done without first consulting the Fire Office and learning what precautions it considers necessary under the particular circumstances of the risk.

In Drapers' Shops and risks of a similar kind the greatest care must be exercised, not only to keep the lamps but all switch-boards, switches and cut-outs at a safe distance from all combustible materials and goods. Too much attention cannot be given with regard to fixing up the work securely, and the utmost care should be taken to render it impossible for goods to come into contact with incandescent lamps or their conductors. No arc lamps to be in any position in a draper's premises that may be deemed undesirable by the Technical Adviser of the Fire Office. No portable lights on flexible conductors should be placed in the shop windows or shops, where there are inflammable goods.

Central Stations, Theatres, Mills and very Hazardous Risks.

No. 38. In very hazardous risks, special precautions may have to be taken, such precautions necessarily varying according to the peculiarity of the circumstances of the hazard.

With regard to Central Stations the buildings should be fireproof, of one storey construction, and lofty. They should contain no match boarding, and not be crowded up. The switch-boards should be fireproof, and so placed that there

be ample room for a man to work securely, safely and comfortably behind them at any time. The positive and negative conductors should be on separate boards where practicable. The work should be on the front of the board as far as possible, and no apparatus of any kind should be placed behind if possible; the surroundings of the switch-boards should be fireproof.

If the conductors are brought to the switch-board by means of a tunnel, the tunnel should be fireproof and contain no other apparatus if possible, and where the conductors pass through the floor, to or from the tunnel, arrangements should be made, so that fire would have difficulty in passing along them.

The temperature of the station should be kept as low as possible.

Too much stress cannot be laid upon keeping the station always clean.

With regard to Theatres, the work should be of a special character—the work in connection with batten, wing and float lights should be incombustible if possible, the switch-board incombustible, and arranged with the view of the minimum amount of danger arising if a fire broke out about it; the work in connection with floor plugs or temporary attachments should be fireproof and special, great care being taken to prevent any liability of heating being set up in them from bad contacts or other causes; fixed conductors on the stage should be in iron or steel tubes or in oak casings or other specially approved casings; any loose conductors should have very strong coverings to their insulation; all lights must be at a safe distance from all inflammable materials; and all work specially protected against liability to injury.

All work should be in circuits, as small as can conveniently be arranged, with double switches and double cut-outs to each. No work to be inside any roof.

In Paper Mills, the greatest precautions must be taken against damp and corrosive vapours or gases.

In Sugar Mills, special precautions have to be taken to

prevent deleterious action from the high temperature, and in some instances from corrosion. In some places it may not be advisable to place up electrical work.

In Saw Mills, great care must be taken, especially with regard to keeping all work free from injury, and also the cut-outs, resistances, switches, switch-boards, etc., free from fine dust; the work should be of the highest class throughout, and in circuits with double switches and double cut-outs to each. The same remarks apply to Cotton Mills; here the materials used and the dust ("fly") given off are more inflammable.

In Printing Works, Corn Mills, etc., special care has to be taken with regard to security.

Again, in risks where naphtha or certain chemicals are used, a solvent action may be set up on the insulation, or the chemicals employed might act upon the electrical work and slowly or quickly eat it away; the conditions might be such that it would not be advisable to place up any electrical work.

Very hazardous risks vary so greatly that each one requires to be separately considered with regard to its special characteristics, and no electrical work should ever be placed up without previously consulting the Fire Office and obtaining its sanction.

Electrical Heating.

No. 39. When any building or portion of a building is to be heated by electricity, notice must be given to the Fire Office; the system and arrangements must be such as meet the approval of the Technical Adviser of the Fire Office, and no electrical heating or arrangements will be allowed in any building or in any part of a building that do not meet with his sanction.

The same general electrical safeguards must be taken with regard to the installation as are required by the rules for an electric light installation, so far as they apply, but with the addition of such other safeguards as are stated here, or may

be considered requisite by the Technical Adviser of the Fire Office.

The same general safeguards for security from fire will be required with regard to electrical radiators, etc. (electric stoves), that would be considered necessary by the Fire Office if the radiators, instead of being heated by electricity, were heated by other means. They will be considered as stoves. Arrangements must be made so that the temperature of the radiators will not exceed that for which permission is given.

All radiators (stoves) must be fixed at such safe distance from wood work and all other combustible substances as may be required by the Fire Office.

No radiator to be fixed in roofs, cupboards, nor in any position or place that may be objected to.

Every radiator should be protected by its own separate cut-outs, and should have double switches.

All radiators should be fixed to, or stand upon, approved fireproof insulators.

All sockets and plugs should be incombustible; they must be to the approval of the Technical Adviser of the Fire Office. No sockets will be allowed in any place nor in any risk that he may consider undesirable.

Floor sockets are not allowed (unless previous written permission has been obtained). If permission to use them be given, the connections must be sweated into thimbles; they must be efficiently protected against mechanical injury, and from damp, and other injurious influences.

Every socket should be so constructed that the contacts are automatically covered when the plug is removed.

The main conductors, and all principal branches, must have a switch and cut-out on each conductor.

The conductors for supplying current to the radiators must be attached to proper terminals of large carrying capacity.

No conductor to be unencased without permission. The insulation upon any unencased conductor must be of special character, and have very strong coverings.

No conductor or any part of the work to be so placed that they will be exposed to mechanical injury.

No conductors to be so placed that they can be exposed to undue heat from the radiators. The insulation of the conductors at the radiators should be special and of fireproof character if necessary.

All work and materials to be of the highest character, and to the satisfaction of the Technical Adviser of the Fire Office. The entire installation (including the insulation resistance of the whole work, both with regard to earth and between conductors) must also be to his satisfaction.

With regard to hazardous risks other special precautions may be required; these, of course, may vary according to the nature and circumstances of the particular risk.

The electric heating installation should be distinct from any electric light installation that may be on the premises, unless permission be given to the contrary.

Any apparatus used for giving off or diffusing heat (unless for cooking purposes) will come under the head of radiator.

Electrical Cooking.

No. 40. The same general rules must be observed as for electric heating, so far as they apply.

Every oven, stove, or other apparatus, should be protected by its own separate cut-outs and switches.

The greatest care must be exercised in so arranging the conductors that there is no possibility of any of them becoming unduly heated, either by proximity or contact with any of the apparatus, or from other causes. Care must also be taken that none of the electrical work is liable to mechanical injury.

The insulation of the conductors at or near the oven, stove or other apparatus may have to be special and of fireproof character.

Special care must be taken with regard to insulation—this refers not only to the installation generally, but to the cooking apparatus itself.

With regard to the cooking apparatus the same general safeguards must be taken with regard to security from danger of fire that would be considered necessary by the Fire Office if the apparatus were heated to similar temperatures by other means; and this applies also to the positions of the apparatus, methods of fixing, distance from and protection of woodwork or other combustible materials, etc.

The whole of the work to be to the satisfaction of the Technical Adviser of the Fire Office.

Character of all Electrical Work.

No. 41. All work and materials to be of the best character; and the installation to be accurately tested at the time of erection for insulation.

All installations should be periodically examined and tested.

Notice should be sent to Fire Office.

No. 42. Before an electrical installation is used notice should be sent to the Fire Office, in order that an opportunity may be given for the installation to be inspected with regard to its fire risk. Full particulars of the proposed installation and all its details should be supplied; the particulars must include a statement of the maximum current to be sent down the various conductors, and the electro-motive force of the current; also if the current is to be direct or alternating, and whether generated on the premises or supplied from a central station. Samples of the conductors must be sent, that they may be examined. Specimens of the cut-outs, protectors, switches and ceiling roses, wall sockets, etc., may be required should the description of them be obscure or unsatisfactory. The above particulars should be sent before any work of an installation is commenced.

Should an electrical installation be altered, or the supply of current altered, notice should be sent to the Fire Office.

No departure from any of these Rules will be allowed, unless permission to do so is given by the Technical Adviser of the Fire Office. The whole of the arrangement, work, fittings and materials of the electrical installation must be to his entire satisfaction.

MUSGRAVE HEAPHY, C.E.,

M. INST. E.E., ETC.

PHŒNIX FIRE OFFICE.

ELECTRICAL FIRE RISK.

USEFUL FACTS TO BE REMEMBERED.

Electricity can readily change to fire.

Any portion of an Electrical Installation improperly placed up, can self-fire from the Dynamo to the Lamp; the parts hidden away being often the most dangerous, whilst the light itself is often the most secure, but even the lamp itself can set fire to inflammable materials if it be in contact with them.

If the passage of Electricity be retarded in any part of its circuit, the current of Electricity develops heat. Bad joints and imperfect connections may get red hot.

Conductors of a certain diameter can only transmit a definite quantity of Electricity safely (for a rough comparison, Electricity going along a conductor may be likened to steam or water passing through a pipe); any amount above that causes them to become dangerously heated. Conductors from this cause have got red, and even white hot; burning their insulating coverings, and setting fire to everything combustible they were in contact with.

If a Positive and a Negative Conductor[1] are placed too near each other, and the insulating material of the conductors happens to get rubbed or worn off, an "Arc" may be set up,

[1] Or, in fact, any two conductors in which the electro-motive force of the Electricity is different.

and fire will ensue. Hence the importance of keeping conductors well apart.

Fires will arise if a "short circuit" takes place; that is, if the Electricity manages to get from one conductor to the other (which it is always anxious to do), without passing through the lights. Anything combustible that the Electricity "short circuits" across may be set on fire. Hence the necessity of good insulation to the conductors.

A fire may break out if leakage of Electricity takes place to "earth." Hence, again, the importance of good insulation, and of keeping conductors free from metal work, such as gas and water pipes, etc.

Moisture will "short circuit" or will "earth" conductors, and has been the cause of several fires, some of which have arisen from washing floors when the conductors have been under. Hence the necessity of waterproof insulation to conductors when situated in damp places, or where any moisture can reach them, and care required in fixing switches, cut-outs, or any bare connections.

There is as much danger from an Incandescent Installation as there is from an "Arc" Installation, if either be not properly put up.

In fixing the position of Dynamo, it must be remembered that many instances have occurred of Dynamos setting themselves on fire. A good deal of sparking may take place at the "brushes," and the "brushes" may burn.

Switches are extremely liable to set up a fire if they get out of order, or are improperly constructed, or not properly fixed.

In laying out Installations do not place too great reliance on "cut-outs," but rather trust to the manner the whole work has been arranged with regard to safety. Experience proves that "cut-outs," invaluable as they are, are no sure protection against an Electric Fire breaking out under certain circumstances. They have even themselves been the cause of fires occurring.

If your lights are burning dim, and your Electrical Machinery is going at its normal speed, then leakage of

Electricity is probably taking place, and an examination should at once be made.

If you switch out your lights with a switch that acts on one conductor only, remember that this does not turn the current off, it is still in the conductors, and a fire can break out under certain circumstances (perhaps in the middle of the night) though not a single light is burning. Turn off your lights therefore by switches that act on both conductors, and so cut the current off entirely.

When an Electrical Fire breaks out, turn off the current from both poles at the nearest switches, then use your appliances; the injudicious use of water without these precautions may only increase the extent of the fire.

NOTE.

If you put up electrical work to tender, remember this: *that any firm by arranging to place inferior quality of work in your premises can easily underprice other firms that are more conscientious;* and experience proves that *inferior work is nearly certain to result in a fire breaking out sooner or later*—perhaps between floors and ceilings, or under roofs. Be careful, therefore, previous to accepting a low tender, to make yourself certain that the *same quality* of work has been estimated for and intended to be done as that of the higher tender.

Keep your installation in such a condition that it would be affected as little as possible by any leakage to earth from the company's mains that supply the current.

Be sure that all connections are kept in good order, and that no screw connection is loose.

The electric light in the opinion of the Phœnix Fire Office is the safest of all illuminants, and is preferable to any other, when the installation has been thoroughly well put up to its satisfaction, and the particular system employed has its approval.

The electric light must not be used in places where other illuminants are not allowed unless special permission to the

contrary has been obtained from the Fire Office. There are also certain risks in which the electric light must not be used without special permission from the Fire Office. This also applies to electric heating, electric power, etc.

THE WESTMINSTER ELECTRIC SUPPLY CORPORATION, LIMITED.

INSTALLATION WORK RULES.

WIRING.

All the work inside houses is to be carried out in accordance with the rules issued by the Fire Insurance Companies.

The insulation resistance of wire used to be not less than—

(1) In dry places: 300 megohms per mile.
(2) In damp places: 600 megohms per mile.
(3) In plaster-work and walls: 1,000 megohms per mile.

No joints should be made in wires which are to be buried in casing in walls.

All joints in the insulation to be covered with at least six laps of pure rubber; the braiding, cotton, or tape should be cut away on either side of the joint, leaving the insulating material and copper conductor to be covered with the pure rubber. When this has been put on the whole may be covered with protecting tapes, each layer to be soaked in india-rubber solution.

BRANCH CIRCUITS.

No switch should turn on at one time more lamps than require a current of 10 ampères. Each branch circuit must be provided with means of disconnecting it on both poles.

No disused circuit is allowed to be left with the current on the wires, but must be cut off close to the mains, or double-pole cut-outs must be introduced between the mains and branch and the fuse wires left out.

Fittings.

In all cases where fittings in connection with gas pipes are used, the whole fitting must be insulated in an efficient manner from the wall and the gas supply pipe, and all the metal lamp-holders must be insulated by ebonite or other suitable material from the fitting.

No combination gas and electric light fittings are to be used unless they have been specially examined and passed by the Corporation's Inspector.

No imitation candles or other fittings of celluloid can be allowed under any circumstances.

Fuses and Main Switch.

Both wires of each circuit to be provided with cut-outs, and at the entrance to each house two single-pole cut-outs and two single-pole switches, or a double-pole cut-out and switch, to be fixed in the house mains.

All fuses should be marked with name-plates, showing what circuits they control.

Main Fuses.

At any time after an installation has been tested and passed by the Inspector, he will, on request, insert the fuse wires in the main cut-out. Under no circumstances whatever must these fuses be inserted by the wiring contractor or by the householder.

If at any later time the Corporation's main fuse should go, the householder should at once send word to the Central Station from which he is supplied with current, which is

always open, in order that the cause of failure may be ascertained and a new fuse inserted.

Testing.

On receipt of notice at the Head Office that the work is ready, the Corporation will send their Inspector, who will make a test and examination free of charge. If it turn out that the installation is not ready for testing, or if it fail to pass the test, a fee of 10*s.* 6*d.* must be paid at the Head Office of the Corporation before another test or inspection can be made.

Notice in writing must be given to the Corporation at their Head Office, by the contractors, at least 48 hours before a supply is required to be turned on.

The Corporation will not supply current to any installation—

(1) If there are any temporary wires or fittings.

(2) If the whole of the work is not completed and all fittings fixed.

(3) If when testing with a pressure of 100 volts the insulation resistance is below the following standard—

For	12 Lamps	...	...	5	megohms.
„	25 „	...	...	2·5	„
„	50 „	...	...	1·5	„
„	75 „	...	...	1·25	„
„	100 „	...	...	1·0	„
„	150 „	...	...	0·75	„
„	200 „	...	...	0·5	„
„	250 „	...	...	0·3	„
„	300 „	...	...	0·2	„

Previous to a test being made by the Corporation's Inspector, every fuse in the whole installation must be inserted, all switches turned on, and the lamps removed; a test for insulation between wires will then be made, and in no case must this insulation fall below 75,000 ohms.

After the test under these conditions is completed all the lamps must be put in, and it is the duty of the Inspector to see that every lamp lights properly.

Pressure.

The current will be supplied at a pressure of 100 or 200 volts at the consumer's main cut-out.

Three-wire System.

In any installation requiring more than 50 ampères, or a large and varied supply of current, or current for motive power, the Corporation reserve to themselves the right of supplying at a pressure of 200 volts, with or without subdivided circuits of 100 volts each.

Motors.

All Motors must be mounted so that they are efficiently insulated from earth; the insulation test required will be in accordance with the above rule, and will be taken at the equivalent number of lamps as represented by the energy required by the Motor. Motors must be wound for a pressure of 200 volts, and the starting current must not under any circumstances exceed 10 ampères, unless special permission to the contrary be given. In every case it is essential that a starting resistance, with a sufficient number of contacts, should be placed in the Motor circuit and so proportioned that the starting of the Motor shall under no circumstances cause visible disturbance to any lights upon its own or neighbouring circuits.

Cooking and Heating Apparatus

must be wound for 200 volts.

INTERNAL WIRING OF BUILDINGS

Arc Lamps.

All arc lamps fixed out of doors must have a porcelain insulator of approved pattern between the lamp and the bracket or support of the lamp, even in cases where the framework of the lamp is not in connection with the circuit. Where the lamp is to be turned on or off, a resistance must be provided to reduce the rate at which the current is thrown on, to the satisfaction of the Inspector. Unless special permission be obtained arc lamps must be so arranged as to take the supply at 200 volts.

Street Lamps.

Where incandescent lamps are used in lamp-posts, and metal frame incandescent lamp-holders are used fixed to a pipe inside the lantern, an insulating piece of ebonite or porcelain must be inserted between the lamp-holder and the pipe to prevent an earth circuit being formed by a faulty lamp or by a strand of the wire used touching the body of the lamp-holder.

Service Mains.

The Corporation, in all cases, lay the service mains between their mains and the consumer's premises.

The Corporation will only bring the service mains into the consumer's premises, at a point nearest to their service manholes, and will fix the end of their service mains into a cut-out box.

The consumer's house mains must be brought out as far as the Corporation's cut-out box, and the ends left ready for sweating in, which will be done by the Corporation.

House mains from the Corporation's service cut-out box into the house, passing through damp vaults or out in the open, must have an insulation resistance of 2,000 megohms per mile, and must be laid in waterproof wood casing, or lead or iron pipes.

The Corporation do not undertake any wiring or other

work which the consumer has to pay for. All such work is to be carried out by the Wiring Contractor.

Meters.

The Corporation supply at a fixed rental all meters to be used on their lighting circuits. Their Inspector will fix the position of the meter, which will be as near the point where the service mains enter the consumer's house as possible. No switches or fuses are to be fixed between the Corporation's cut-outs and their meter. To avoid expense it is most desirable that the Corporation should be communicated with while the work of installation is in progress, in order that the place for the meter and cut-outs may be fixed as early as possible, the householder having previously made proper application to the Corporation for a supply of current.

The Contractor must leave a bight of from 5 to 6 feet long for the connection to the meter, but these connections will in all cases be made by the Corporation.

Leakage.

In the event of the insulation resistance of an installation falling below 5,000 ohms, after a supply has been turned on, and if the servants of the Corporation are not allowed to find or remedy the fault, the whole of the installation will be cut off until the fault has been put right; any expenses the Corporation are put to in finding such fault are to be repaid to the Corporation by the consumer.

Any circuit which is found defective by the Inspector will be disconnected from the supply, and a printed notice will be affixed at the junction of this circuit with the supply, forbidding the use of this defective circuit until put in order and passed by the Inspector.

Increase of Lighting.

In the event of an increase in the lighting of an installa-

tion after a supply has commenced, necessitating alterations or additions to the wiring, notice in writing to the Corporation must be given, and all such work will be tested by the Corporation when finished, prior to turning on the increased supply.

Failure of such notice is liable to enforce the Corporation to cut off the whole installation (*vide* leakage).

The Act provides that in case of Electric energy being used or dealt with by any Consumer in such a manner as to "unduly or improperly interfere with the efficient supply of energy to any other body or person," the Corporation may, if they think fit, discontinue the supply so long as such interference continues.

RULES OF THE INSTITUTION OF ELECTRICAL ENGINEERS.

GENERAL RULES RECOMMENDED FOR WIRING FOR THE SUPPLY OF ELECTRICAL ENERGY.

These rules embody the chief precautions and requirements which the Institution considers necessary to secure satisfactory results.

They have been drawn up to meet the ordinary cases of dwelling-houses, offices, or business premises in which it is desired to lay the conductors, and fix the fittings and appliances necessary for utilizing electrical energy either for lighting, for heating, for motive power, or for other purposes.

They are arranged in such a form that they may be used as a specification of requirements and precautions, which must be strictly enforced if a user of electrical energy wishes to have his house or premises supplied in such a manner that he may be as free as possible from risk of fire, of extinction, failure of supply, or danger to person, and at the same time have his work carried out with due regard for economy both in first cost and in after cost of maintenance.

The rules are framed to meet all ordinary cases, but they are not intended to take the place of detailed specifications drawn up by consulting engineers to meet individual requirements.

They are confined to a statement of well-ascertained requirements, and do not recommend any special system or form of apparatus by which these may be best fulfilled.

For convenience the rules are grouped as below.

Conductors.	1.	Conductivity and size.
	2.	Insulation.
	3.	Joints.
	4.	General arrangement.
	5.	Precautions where they pass through walls or partitions.
	6.	Precautions at points of connection.
Fittings.	7.	Precautions as to switches, fuses, and other appliances.
	8.	Switches.
	9.	Switch-boards.
	10.	Fuse boxes and fuses.
Generating and Utilizing Appliances.	11.	Dynamos and motors.
	12.	Accumulators or other batteries.
	13.	Transformers.
	14.	Arc lamps.
	15.	Testing the whole and parts.

Conductors—Conductivity and Size.

1. They should be of high-conductivity copper, not less than 100 per cent. conductivity, and, where sulphur or other substance liable to attack bare copper is contained in the insulation, they should be tinned with pure tin.

Note.—The standard of conductivity here referred to is, that the resistance of a copper wire weighing 100 grains, 100 inches long, should be 0·1516 ohm at 60 degrees Fahr.

Their sectional area should be proportional to the heating effect of the current required for the maximum number of lamps, or other current-using apparatus, that can be used simultaneously on the circuit; but in no case should the sectional area of any conductor be less than that of a No. 18 S.W.G. wire. All conductors having a sectional area larger than that of a No. 14 S.W.G. wire should be stranded.

They should be of such size that, when the maximum current is passing continuously through them, their temperature shall not exceed 130 degrees Fahr. It will, however, generally be found that, if the conductors are worked up to a density of current corresponding to this increase of temperature, the resulting fall of potential or drop in volts will be inconvenient and uneconomical. It is imperative that this temperature of 130 degrees Fahr. should never be exceeded, and therefore it is necessary to take into account the maximum temperature to which they may be subjected, independently of electric heating, in each particular locality, and the greatest increment above this temperature should not be more than will raise them to a temperature of 130 degrees Fahr.

If the maximum temperature of the British Islands be taken as 100 degrees Fahr., then the increment due to electric heating must not exceed 30 degrees Fahr.; that is to say, the size of the wires should be such that, when carrying the maximum current continuously for many hours, the temperature does not rise more than 30 degrees Fahr. above the temperature, for the time being, of the place in which they are situated. In specially hot places the wires should be so large that the electric heating should be almost nil, and the wires should be specially insulated with insulating material which does not deteriorate at the highest temperature to which it will be subjected.

The Table appended shows size of conductors which will safely carry currents up to 740 ampères, and the length in yards of single conductor in circuit for each volt of fall of potential when the maximum current is in use.

INSULATION.

2. Insulated conductors may be broadly classed under two heads—

A. Those insulated with a material as a dielectric which is itself so impervious to moisture that it only needs further protection from mechanical injury or from vermin.

B. Those insulated with a material as a dielectric which, in order to preserve its insulation qualities, must be kept perfectly dry, and therefore needs to be encased in a waterproof tube or envelope, generally of soft metal, such as lead, which is drawn closely over the dielectric.

When class A is used, the dielectric must be perfectly damp-proof, and not in any case less in thickness, measured radially, than 30 mils plus 1–10th of the diameter of the conductor; it should not soften at a lower temperature than 170 degrees Fahr.; the minimum insulation of a test piece cut from it should be that given in column 7 of the Table, the test being made at 60 degrees Fahr. after one minute's electrification, and after the test piece has been immersed in water for 24 hours.

When class B is used, the same conditions as to minimum thickness and softening temperature of the dielectric should be enforced as in class A; its covering should be such that a test piece cut from the conductor and immersed in water will not break down when an alternating pressure of 2,500 volts having a frequency of from 40 to 100 periods per second is applied for 10 minutes between the conductor and the water, the test piece previous to immersion having been bent six times (three times in one direction and three times in the opposite direction) round a smooth cylindrical surface not more than 12 times the diameter of the conductor, measured outside the dielectric. The coil from which the test piece was cut should be tested in a similar manner to class A, but the minimum insulation resistance should be that given in the Table, column 8.

Conductors of class A must be protected from mechanical injury by being covered with stout braid or taping, prepared so as to resist moisture, and must be further protected by casing, or by being drawn into pipes or conduits.

In the case of conductors insulated as in class B great care must be taken to protect exposed ends of conductors where they enter the terminals of switches, fuses, and other appliances, from the possible access of moisture which might creep along the insulating material within the waterproof covering.

Concentric conductors should in all respects conform to the requirements herein laid down for single conductors; the insulation resistance of the outer dielectric should be that given in the table for single conductors having the same diameter as the outer conductor. The insulation resistance of the dielectric separating the two conductors should be twice that of the outer dielectric.

The bending test of concentric conductors, class B, should be made round a cylinder 12 times the diameter of the outer dielectric.

Flexible cord conductors—*i.e.*, those made up of a number of wires not larger than No. 29 S.W.G., which are then insulated (in many cases two such conductors are twisted together so as to form a double conductor)—should only be used for attachment to portable appliances, or for the wiring of fittings; the insulating material used as the dielectric should be either pure rubber or vulcanized rubber of the best quality. If pure rubber be used, it should be laid on in two laps, care being taken that these should lap-joint. The radial thickness of the dielectric should never be less than 16 mils for pressures up to 125, or 20 mils for pressures up to 250 volts. Each coil should bear a certificate that a piece one yard in length cut from it has withstood for five minutes an alternating pressure of 1,000 volts having a frequency of from 40 to 100 periods per second applied between the two conductors twisted together, the piece being subjected during the test to the vapour arising from a pan of boiling water

placed at a distance not exceeding 3 feet, and immediately below it.

Joints.

3. All joints in conductors must be mechanically and electrically perfect, to prevent heat being generated at these points. The use of soldering fluids containing hydrochloric acid, sal ammoniac, or other corrosive substances, should be absolutely forbidden. The insulation of all joints in insulated conductors should be most carefully attended to, the object being to make the insulation of the joints as nearly as possible equal to the insulation of the remainder of the conductor.

In jointing rubber-insulated cable, care should be taken that the braiding or taping is carefully removed without damage to the india-rubber, which latter should be laid bare, and tapered for sufficient length to ensure a water-tight union with the insulating substance used as a covering. It should be remembered when arranging for any system of wiring that joints constitute a source of weakness, and they should, therefore, be avoided as far as possible.

General Arrangement.

4. The arrangement of conductors should be carried out as far as possible from distributing centres, the cable conveying the current to them being free from joints; from these centres of distribution the use of small circuits carrying up to 5 ampères, and also free from joints, except at the branches and connections to switches and other appliances, is recommended, in order that the fuses at these centres of distribution may amply protect every conductor beyond them, even if only a "flexible" for a single lamp.

This will ensure safety, although the ideal system is to carry a conductor from each point of use back to the distributing centre without joint or tapping.

The use of a draw-in system in which both conductors are drawn into one strong incombustible tube or chamber, or their equivalent, is preferable to wood casing with spaced conductors, as safety is better obtained by the use of suitable insulation of the wires themselves than by trusting to the wood casing, or to the spacing for insulating purposes. The composition of the tubing or conduit used must depend on the character of the structure in which it is embedded; tubes or conduits which minimise condensation or sweating are to be preferred. When tubes are used no elbows should be employed, but corners should be turned either by means of slow bends or by the fixing of a suitable box.

Conductors spaced and separated away from the walls should not be permitted unless they are mechanically protected throughout their entire length. Where the distribution is effected by circuits not carrying more than 5 ampères, conductors of the same polarity may be "bunched" together, providing a double-pole fuse, arranged to sever the circuit before any perceptible rise of temperature can take place, is inserted at the point of distribution; conductors of opposite polarity may also be "bunched," provided that they are placed in an incombustible tube or conduit.

Precautions where Conductors pass through Walls or Partitions.

5. Cables or wires passing through walls require additional protection, such as a porcelain or other tube, which can be filled up with sand or other chemically inert incombustible material, so as to prevent the spread of fire through these openings. Wherever conductors cannot be in sight, they should be made as accessible as possible; and it is recommended that wires which must be buried within walls should not be fixed, but drawn into channels previously prepared for them, and they should preferably not be drawn in until any dampness which may exist in these channels has dried out of them.

Conductors should not be placed near gas pipes.

Precautions at Points of Connection.

6. Wherever conductors are connected on to switches, fuses, or other appliances, great care must be taken that the whole of the separate wires forming the stranded or flexible conductor are neatly twisted together and clamped into the terminal, so that no loose wire or strand can project; the insulating material or dielectric should only be bared back sufficiently to allow of the conductor entering into the terminals properly, and the ends of the insulation should be thoroughly sealed to prevent moisture creeping along the copper beneath the insulation.

The braiding, lead, or other non- or semi-insulating material, should be cut back for a distance of not less than ¾-inch from the end of the insulating material.

Precautions as to Switches, Fuses, Connectors, and other Appliances.

7. These should be mounted on bases made of porcelain or other non-combustible material. If any difficulty arises through damp, this may be overcome by inserting a second base or backing of specially prepared material.

In excessively damp places, such as cellars, all fittings attached to walls should, as far as possible, be dispensed with, the wires being carried direct from the distributing board to the lamps.

Resistance coils should in all cases be carried on frames or supports made of incombustible material, and preferably should be enclosed in metal cases to prevent accidental derangement.

Wherever fittings, such as brackets, electroliers, or standards, require to have the conductors threaded through tubes or channels formed in the metal work, these should be designed so as to avoid sharp angles or rough projecting edges which would be liable to strip or cut or damage the insulating material in the act of drawing in the conductors, or in fastening them to the outside in the case of adapted

fittings. The use of combined gas and electric fittings should not be permitted; where gas fittings are adapted, they should be insulated from the gas pipe.

Where possible, the conductor should be carried without joint through the fitting to the lamps; but where connections at the back are unavoidable, special care must be taken to make this joint equal in quality, as regards conductivity and insulation, to the rest of the work.

Switches.

8. Every switch, whether fixed separately or combined with lamp-holders or fittings, should be constructed to comply with the following requirements:—

(*a*) That no overheating can take place at the point of contact or elsewhere.

(*b*) That when being switched off it is impossible for a permanent arc to be formed.

(*c*) That it cannot be left in an intermediate position between on and off.

(*d*) The base should be of incombustible material.

(*e*) The cover should also be of incombustible material, and should preferably be either made of or lined with non-conducting material.

(*f*) Covers of all switches should be kept clear of all the internal mechanism.

(*g*) The handles of all switches should be efficiently insulated from the circuit.

(*h*) In order to ascertain that switches comply with the above requirements, samples should be selected from each pattern and size used, and should be tested at an E.M.F. and current 50 per cent. in excess of that which will be used on the circuits for which they are intended.

Main switches should be placed close to the generators if the supply is generated within the building, or at the trans-

former if transformed within the building, or at the point of entrance of the conductors into any building supplied from an external source.

When all three wires of a three-wire system are brought into a house, the member of the switch connected to the middle wire must not make contact later, or break contact sooner, than the other two members; preferably, the middle member should make contact *sooner*, and break contact *later*, than the two outer members. Single-pole switches should not be on the middle wire of a three-wire system. In a five-wire system the same principles will apply.

Switch-boards.

9. Wherever main or centres of distribution switch-boards are provided, these should be constructed of incombustible material, preferably with front connections, with circuits arranged as far as possible to form their own diagram of connections, and so labelled that they may be easily identified. Where back connections are permitted, they should be carefully soldered. Exposed metal work of different polarity on switch-boards should be well separated, and preferably mounted on separate bases.

Fuse Boxes and Fuses.

10. Branches from all circuits should have fuse boxes made of porcelain or other incombustible material on both poles, and the fuses in these fuse boxes, if on the same base, should be in separate compartments. Where the tree, or tapered, system of wiring is allowed, fuses should be introduced at such intervals that each fuse protects the smallest branch between it and the next fuse; or, if there is no other fuse, then it must protect right up to the end of the circuit. If the above precautions are taken, it is not necessary to protect the ceiling roses which support flexible pendants by fuses at the ceiling point of junction.

Whenever circuits not exceeding 5 ampères have fuses in

each pole at the distributing point, fuses in the connectors (see Section 7) are not necessary; should the current, however, exceed 5 ampères up to 125 volts, or 3 ampères up to 250 volts, all portable fittings requiring flexible cords, or adapted fittings wired with flexible cords, must be protected with a fuse at the point of junction with the circuit.

Any fitting containing many lights, and wired with flexible cord, should be supplied by conductors carried back to the distributing centre.

Where one of the conductors is connected to earth, all switches and fuses which will be single-pole should be arranged on the insulated side of the system.

No fuses or switches should be placed in or at any point of the earthed conductor.

Standard types of fuses should be so designed as to avoid the risk of inserting fuses intended for large circuits into the fuse carriers of small circuits, and *vice versâ*.

The covers of all fuse boxes—whether these be separate or grouped on switch-boards—should be efficiently ventilated, so as to avoid risk of fracture by the sudden expansion of the air within them at the time the fuse melts, the covers being arranged to catch and retain the fused metal.

All connectors should be capable of withstanding a test at an E.M.F. and current 50 per cent. in excess of that for which they are intended. If used in damp places, special precautions must be adopted to exclude moisture. In cases where the fixed part of the connector is attached to a floor, it must be so arranged that no dust or water can accumulate in the cavity, and should have all contacts well below the floor level, to prevent any possibility of danger from contact with the carpets.

When concentric connectors are used, they must be constructed so that they cannot be readily short-circuited by a piece of metal, such as a pin or a metal pencil-case. Clearances should be such that an arc cannot be started if the connector is pulled out at the time that the current is flowing. The insulation used between opposite poles should be such that it will not readily break or chip.

Dynamos and Motors.

11. Dynamos and motors should be protected from damp and dust, and should be so placed that no woodwork or inflammable material is within a distance of 12 inches from them measured horizontally, or within 4 feet from them measured vertically above them; and the same precautions must be adopted in placing and fixing the starting switches or regulating resistances used in connection with any of these appliances. The coils of these resistances must be so designed that in no case do they heat above 212 degrees Fahr. even if left continuously in use; and the coils must be protected by suitable metal casing or guards, which must not interfere with free circulation of the air round the coils.

The frames of dynamos or motors employing an E.M.F. of 250 volts or upwards should be connected to earth.

Continuous-current transformers are to be classed with dynamos and motors.

Accumulators or other Batteries.

12. Both accumulators and primary batteries should be placed and used under the same precautions as above described for dynamos and motors, and the room in which they are placed should be well ventilated. The accumulators and batteries should themselves be well insulated from the earth, and should be protected by fuses at both poles, and at all points of connection between the circuit and the regulating cells.

Transformers.

13. When these are used to transform either direct or alternating currents of high E.M.F. down to the E.M.F. allowed by the Board of Trade on the consumer's premises, they, together with their switches and fuse boxes, must be placed in a fire- and water-proof structure, preferably outside

the building for which they are required, and their frames must be connected to earth.

No part of such apparatus should be accessible except to the person in charge of them. In all cases conductors conveying currents of high E.M.F. inside a building must be specially insulated and encased in a fire-proof conduit. Under no circumstances should transformers be allowed to heat under normal conditions of load to a temperature of 150 degrees Fahr. Transformers should be so protected by suitable apparatus that a leak between the primary and secondary coils raising the pressure to 400 volts above that of the earth should cut the transformer out of circuit.

Low-pressure alternating transformers or choking coils may be placed within buildings, but the same precautions as regards heating of the coils, distance from woodwork, and guarding must be adopted as in the case of resistances used for motors.

Arc Lamps.

14. Arc lamps must always be guarded by lanterns or netted globes, so as to prevent danger from ascending or descending sparks, and from falling glass or incandescent pieces of carbon. All parts of the lamps which are liable to be handled should be well insulated, and, in addition, an insulator must be inserted between the lamp and its support. Resistances for arc lamps should have a similar double insulation; their coils should be designed so as not to heat above 212 degrees Fahr.; they should be protected by metallic ventilating guards, and should be so placed that no woodwork is within 6 inches of them measured horizontally, or within 2 feet of them measured vertically above them. When arc lamps are supplied from constant potential mains, fuses on both mains are necessary.

Arc lamps in which air can have access to the carbons during burning should on no account be used in places where inflammable vapours or explosive mixtures of dust or gas are liable to be present.

Testing.

15. The conductors, fittings, and appliances must be tested in the following manner before the current is switched on:—The whole of the lamps or appliances for utilizing the energy having been connected to the conductors, and all fuses being in place, an E.M.F. equal to twice the E.M.F. which will be ordinarily used is to be applied, and the insulation resistance between the whole system and earth must be measured after one minute's electrification. The insulation should then not be less than 10 megohms, divided by the maximum number of ampères required for the lamps and other appliances. The installation may be then set to work, and a second and similar test should be made after an interval of 15 days. In each test, if the insulation of the whole is below standard, the work should be divided up by the departmental switches and tested separately, in order to locate the faulty section.

The value of systematically testing and inspecting apparatus and circuits cannot be too strongly urged as a precaution against fire. Records should be kept of all tests, so that any gradual deterioration of the system may be detected. Cleanliness of all parts of the apparatus and fittings is essential. No repairs or alterations should be made when the current is "on."

Explanation of Table.

Column 1 gives the sizes of the conductors in common use. Cables are shown thus:—19/14, viz., 19 wires of No. 14 Standard wire gauge.

Column 2 gives the maximum current for situations where the external temperature is above 100 degrees Fahr.

The current for any conductor may be calculated from the formula—

$$\text{Log } C = 0{\cdot}775 \log A + 0{\cdot}301,$$
$$\text{or } C = 2\ A^{0{\cdot}775}$$

(where C = current in ampères, A = area in 1,000ths of a sq. in.).

The maximum rise in temperature will be about 10 degrees Fahr. on large sizes.

Column 3 gives the total length in yards of lead and return of each size of conductor causing a drop of 1 volt when transmitting the current shown in column 2.

Column 4 gives the maximum current allowable in any situation. The current for any conductor may be calculated from the formula—

$$\text{Log } C = 0{\cdot}82 \log A + 0{\cdot}415,$$
$$\text{or } C = 2{\cdot}6\, A^{0{\cdot}82}$$

(where C = current in ampères, A = area in 1,000ths of a sq. in.).

The maximum rise in temperature will be about 20 degrees Fahr. on large sizes.

Column 5 gives the total length in yards of lead and return of each size of conductor causing a drop of 1 volt when transmitting the current shown in column 4.

Column 6 gives the minimum thickness of dielectric. This may be obtained for any conductor by adding 30 mils to 1–10th the diameter of the conductor.

Columns 7 and 8 give the insulation resistances in megohms for one mile of cable of classes A and B respectively.

By Order of the Council.

F. H. WEBB, *Secretary.*

Offices of the Institution,
28, Victoria Street, Westminster,
July, 1897.

TABLE SHOWING MAXIMUM CURRENTS, THICKNESS OF DIELECTRIC, AND INSULATION RESISTANCE FOR COPPER CONDUCTORS INSULATED AND LAID IN CASING OR TUBING.

1.	2.	3.	4.	5.	6.	7.	8.
Size, S.W.G.	Maximum Current for High External Temperatures.	Total Length in Yards of Lead and Return giving 1 Volt Drop.	Maximum Current Allowable.	Total Length in Yards of Lead and Return giving 1 Volt Drop.	Minimum Thickness of Dielectric in Mils or Thousandths of an Inch.	Minimum Insulation Resistance in Megohms for One Mile of Class A.	Minimum Insulation Resistance in Megohms for One Mile of Class B.
18 or 62/38 or 97/40	3·1	23	4·2	18	35	1,200	300
3/22	3·3	23	4·4	17	36	"	"
17 or 130/40	4·0	25	5·4	19	36	"	"
3/20	4·8	26	6·6	19	38	"	"
16 or 110/38 or 172/40	4·9	27	6·8	19	36	"	"
15	5·9	28	8·2	20	37	800	"
7/22	6·2	28	8·7	20	38	"	"
14 or 172/38 or 7/21½	7·0	29	9·8	21	38	"	"

3/18	7·5	30	11·0	20	40	600	,,
7/20	9·3	31	13·0	22	41	,,	,,
7/18	14·0	37	21·0	25	44	,,	,,
19/20	20·0	39	30·0	26	48	,,	,,
7/16	23·0	40	34·0	27	49	,,	,,
19/18	31·0	45	48·0	29	54	,,	,,
7/14	32·0	45	49·0	29	54	400	,,
19/16	49·0	51	77·0	32	62	,,	,,
19/14	70·0	56	110·0	35	70	,,	,,
37/16	83·0	59	130·0	37	75	,,	,,
19/12	100·0	66	170·0	39	82	300	,,
37/14	120·0	64	190·0	40	86	,,	,,
61/15	150·0	67	240·0	42	95	,,	,,
61/14	170·0	74	290·0	43	102	,,	,,
37/12	180·0	73	300·0	44	103	,,	,,
61/12	260·0	82	450·0	47	124	,,	,,
91/12	350·0	90	620·0	51	144	,,	,,
91/11	420·0	94	740·0	53	158	,,	,,

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Butler & Tanner, The Selwood Printing Works, Frome, and London.